98th Congress
2d Session

COMMITTEE PRINT

S. PRT.
98-248

THE STATUS OF ENVIRONMENTAL ECONOMICS: THE 1984 UPDATE

A REPORT

FROM THE

ENVIRONMENT AND NATURAL RESOURCES POLICY DIVISION

OF THE

CONGRESSIONAL RESEARCH SERVICE

OF THE

LIBRARY OF CONGRESS

FOR THE

COMMITTEE ON
ENVIRONMENT AND PUBLIC WORKS
UNITED STATES SENATE

NOVEMBER 1984

Printed for the use of the Committee on Environment and Public Works

U.S. GOVERNMENT PRINTING OFFICE
39-615 O WASHINGTON : 1984

S 322-10

COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

ROBERT T. STAFFORD, Vermont, *Chairman*

HOWARD H. BAKER, Jr., Tennessee
JOHN H. CHAFEE, Rhode Island
ALAN K. SIMPSON, Wyoming
JAMES ABDNOR, South Dakota
STEVE SYMMS, Idaho
PETE V. DOMENICI, New Mexico
DAVE DURENBERGER, Minnesota
GORDON J. HUMPHREY, New Hampshire
DANIEL J. EVANS, Washington

JENNINGS RANDOLPH, West Virginia
LLOYD BENTSEN, Texas
QUENTIN N. BURDICK, North Dakota
GARY HART, Colorado
DANIEL PATRICK MOYNIHAN, New York
GEORGE J. MITCHELL, Maine
MAX BAUCUS, Montana
FRANK R. LAUTENBERG, New Jersey

Bailey Guard, *Staff Director*
John W. Yago, Jr., *Minority Staff Director*

THE STATUS OF ENVIRONMENTAL ECONOMICS: THE 1984 UPDATE

Prepared Under Contract by Joseph P. Biniek

CONTENTS

Page

Letter of Request IX
Letter of Submittal X
Executive Summary 1
Introduction 9
Data on and Assessment of Pollution Control Costs 12
  A. Cost Surveys 12
    Bureau of Economic Analysis 12
    Bureau of Census 18
    McGraw-Hill 24
    Council on Environmental Quality 29
    Environmental Protection Agency 34
    American Petroleum Institute 35
    Summary 39
  B. Impact Assessment 40
    Data Resources Incorporated 41
    Putnam, Hayes and Bartlett, Inc 48
    Bureau of Economic Analysis 50
    Public Interest Economics Foundation 53
  C. Siting 57
    Flight of Industry 58
    Delay of Construction 60
Benefit-Cost Analysis in Environmental Decisionmaking 63
  Evolution of Benefit-Cost Analyses 64
  Benefit-Cost Analysis and Decision-Making 66
  Damage Estimates 69
  Benefit Assessments 76
  Costs 80
  Executive Order 12291 82
New Economic Techniques for Pollution Control 84
  Early Bubble Proposals 84
  Broadening the Economic Techniques 86
  Emission Charges 90
    Acid Rain Taxes 90
    Superfund 92
Changing Role of Economics 97
  Market Failure 99
  Costs 106
  A New Concern for Efficiency 113

TABLES

Table 1—Major Data Sources on Environmental Economics 13
Table 2—New Plant and Equipment Expenditures by U.S. Nonfarm Business: Total and for Pollution Abatement 15
Table 3—New Plant and Equipment Expenditures for Pollution Abatement in Current and Constant Dollars 16
Table 4—New Plant and Equipment Expenditures by U.S. Nonfarm Business for Air and Water Pollution Abatement by End-of-Line Methods 19
Table 5—New Plant and Equipment Expenditures by Selected U.S. Nonfarm Business: Total and for Pollution Abatement, 1982 20
Table 6—Total New Capital Expenditure and Pollution Abatement Expenditures for New Plant and Equipment. BEA and Census, by Industry Group 1979 to 1981 22

Page
Table 7—Pollution Control Expenditures as a Percent of Capital Spending—Historical ... 25
Table 8—Total Pollution Control Expenditures—Historical ... 27
Table 9—Investment for Pollution Control ... 30
Table 10—Estimated Incremental Pollution Abatement Expenditures 1979-88. 31
Table 11—Estimated Total Pollution Abatement Expenditures, 1979-88 ... 33
Table 12—Cost of Air and Water Pollution Control ... 36
Table 13—Environmental Expenditures by API: Summary Tabulation ... 38
Table 14—Estimated Incremental Operating and Maintenance Costs for Pollution Control 1970-1987 ... 43
Table 15—Estimated Incremental Investment for Pollution Control, 1970-1987 44
Table 16—Ratio of Expenditure Forecasts to Actual Expenditures ... 51
Table 17—Ratio of Estimated to Actual Sticker Price Increases ... 52
Table 18—Summary of Findings ... 55
Table 19—Reasons Given for Costly Project Delays in Survey of 50 Firms ... 62
Table 20—Estimated Damages of Air Pollution for 1973 ... 71
Table 21—Availability and Reliability of Information on Air Pollution ... 72
Table 22—Estimated National Damage of Water Pollution 1973 ... 74
Table 23—Availability and Reliability of Information for Water Pollution Damages ... 75
Table 24—Air Pollution Control Benefits Enjoyed in 1978 ... 77
Table 25—Benefits in 1983 from Removal of Conventional Water Pollutants ... 79
Table 26—U.S. Energy Consumption by Fuel Type 1850-1980 ... 98
Table 27—Vehicle Miles of Travel and Fuel Consumption ... 100
Table 28—Pesticide Production by Type, 1950-1981 ... 101

CHARTS

Chart A—Capital Expenditures for Pollution Abatement by State 1981 ... 23
Chart B—Estimated Annual Air Pollution Damage Costs ... 110

SELECTED READINGS

Cost Surveys:

"Pollution Abatement and Control Expenditures, 1972-81." Survey of Current Business. February 1983 ... 119
"Plant and Equipment Expenditures by Business for Pollution-Abatement, 1982 and 1983." Survey of Current Business. June 1983 ... 128
"Pollution Abatement Costs and Expenditures, 1981." Bureau of Census. MA-200 (81)-1 ... 131
"16th Annual McGraw-Hill Survey of Pollution Control Expenditures, 1983-86." McGraw-Hill Publications Company. May 1983 ... 145
"Economics." Excerpt from Environmental Quality. The Eleventh Annual Report of the Council on Environmental Quality. December 1980 ... 162
"The Cost of Clean Air and Clean Water." Annual Report of the Administrator of EPA. Excerpt from Document No. 96-38 ... 177
"Environmental Expenditures of the United States Petroleum Industry 1970-1979." American Petroleum Institute ... 209

Impact Assessment:

"The Macroeconomic Impact of Federal Pollution Control Programs. 1981 Assessment." Data Resources, Inc. July 14, 1981 ... 229
"Comparison of Estimated and Actual Pollution Control Cost for Selected Industries." Putnam, Hayes & Bartlett, Inc. February 1980 ... 263
"Pollution-Abatement Programs: Estimates of Their Effect Upon Output Per Unit of Input, 1975-78." Survey of Current Business. August 1979 ... 303
"The Economic Effects of the Clean Air Act." Public Interest Economics Foundation. March 1982 ... 305

Siting:

"Siting New Industry: An Environmental Perspective." Conservation Foundation. October 1982 ... 345
"Siting New Industry: An International Perspective." Conservation Foundation ... 380

Benefit-Cost Analysis:

"Critical Review of Estimating Benefits of Air and Water Pollution Control." EPA-600/5-78-014 ... 401
"The Benefits of Air and Water Pollution Control: A Review and Synthesis of Recent Estimates." A report prepared for the Council on Environmental Quality. A. Myrick Freeman ... 591

Benefit-Cost Analysis—Continued Page
  "Federal Regulations, Executive Order, 12291." February 17, 1981 605
New Economic Techniques:
  "Emissions Trading Policy Statement." 47FR15076. April 7, 1982 611
  "Emission Trading: An Overview of the EPA Policy Statement." National Science Foundation. May 1982 623
  "An Economic Incentive Approach to Controlling Acid Rain." Congressional Record. December 14, 1983 658
  "H.R. 4483. Acid Deposition Control Act of 1983" 659
  "S. 2001. National Acid Deposition Control Act of 1983" 667
  "H.R. 3400. National Acid Deposition Control Act of 1983" 689
  "Technologies and Management Strategies for Hazardous Waste Control." Excerpt from Office of Technology Assessment 712
Changing Role of Economics:
  "The Environment and National Values." Excerpt from the 12th Annual Report of the Council on Environmental Quality 719
  "Effects of Environmental Regulation on Industrial Compliance Costs and Technological Innovation." National Science Foundation. April 1983 739
  "Low-or Non-Pollution Technology Through Pollution Prevention." Prepared by 3M Company for the United Nations Environmental Programs 835

ROBERT T. STAFFORD, VT., CHAIRMAN

HOWARD H. BAKER, JR., TENN.
PETE V. DOMENICI, N. MEX.
JOHN H. CHAFEE, R.I.
ALAN K. SIMPSON, WYO.
JAMES ABDNOR, S. DAK.
STEVE SYMMS, IDAHO
SLADE GORTON, WASH.
FRANK H. MURKOWSKI, ALASKA

JENNINGS RANDOLPH, W. VA.
LLOYD BENTSEN, TEX.
QUENTIN N. BURDICK, N. DAK.
GARY HART, COLO.
DANIEL PATRICK MOYNIHAN, N.Y.
GEORGE J. MITCHELL, MAINE
MAX BAUCUS, MONT.

BAILEY GUARD, STAFF DIRECTOR
JOHN W. YAGO, JR., MINORITY STAFF DIRECTOR

United States Senate
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
WASHINGTON, D.C. 20510

October 31, 1983

Honorable Gilbert Gude
Director
Congressional Research Service
Library of Congress
Washington, D.C. 20540

Dear Mr. Gude:

The Committee on Environment and Public Works has been kept abreast of the field of environmental economics by a series of reports prepared by Mr. Joseph P. Biniek, who at the time was on the staff of the Environment and Natural Resources Policy Division of the CRS. These have included a 1975 report, "The Status of Environmental Economics," issued as a committee print, and a 1979 update, also issued as a committee print.

As several years have passed since the update and since significant changes have occurred both in the economy and in the level of experience in implementing environmental legislation over that time, it would be extremely useful to the Committee for CRS to prepare a new update. The update should not only review and bring up to date information on estimates of pollution control costs and benefits, but also it should review the status of economic techniques being incorporated in environmental protection controls, such as "bubbles" and "emissions trading."

We would appreciate receiving this update as soon in 1984 as possible so it would be available when the Committee begins its work of the second session next year.

If you have further questions about this request, please contact Curtis Moore of the Committee staff. He can be reached at 224-5761.

Sincerely yours,

Robert T. Stafford

Robert T. Stafford
Chairman

RTS/cam

Congressional Research Service
The Library of Congress

Washington, D.C. 20540

LETTER OF SUBMITTAL

June 28, 1984

Honorable Robert T. Stafford
Chairman, Committee on Environment and Public Works
United States Senate
Washington, D.C. 20510

Dear Mr. Chairman:

I am pleased to submit this report on "The Status of Environmental Economics: The 1984 Update." The report and the accompanying readings were prepared by Joseph P. Biniek, Consultant, under the direction of John E. Blodgett of the Environment and Natural Resources Policy Division

As you requested, this report updates the earlier studies prepared by Mr. Biniek when he was on our staff. This report reviews the various estimates of the costs of pollution control; the attempts to evaluate benefits and costs; siting issues; bubbles, emissions trading and banking; and the changing role of economics.

I hope this report will be useful to you and your Committee in your continuing consideration of environmental policy options.

Sincerely,

Gilbert Gude

Gilbert Gude
Director

EXECUTIVE SUMMARY

During the past decade substantial criticism has been directed at Government regulation. Critics contend that regulations have contributed to many problems that plague the Nation. The costs of regulation are said to be excessive, and to contribute to inflation, unemployment, and flight of industry. There are calls for the use of benefit-cost analysis to facilitate environmental decisionmaking. Others contend that the present system is basically sound. This report examines recent attempts to improve the environmental economic data base and decisionmaking. The overview focuses on the following types of studies: costs of pollution control; impact of environmental expenditures; siting problems; benefit-cost analysis; economic techniques for pollution control; and the present status of environmental economics.

Costs of Pollution Control

The history of environmental cost estimating has been controversial. Each estimate is unique, and each estimate suggests a different impact.

The Bureau of Economic Analysis (BEA) began a survey of expenditures in 1973 within the framework of the national economic accounts. The BEA annual survey of 10,000 companies relies on the company as the reporting unit. Each company files a report for its entire operation and the report is classified by industry according to the primary or largest activity. Companies classified as manufacturing include other activities such as retailing, mining, transportation, and services. The BEA data are aggregated to show end-of-the-line and changes-in-production-processes.

The Bureau of Census also has a survey which relies on the business establishment as the source of information. The annual census questionnaire covers 20,000 manufacturing establishments and covers only the particular location engaged in manufacturing. Thus, the census estimates are lower than those published by BEA. However, they are considered more precise for the specific manufacturing category than the BEA estimates.

Industry estimates, such as that by the American Petroleum Institute (API), cover only one sector of the economy. The API annual estimates may differ significantly from the BEA or Census estimates in that the participants are asked to include all expenditures reported to BEA or to the Census and all other expenditures used to modify products for environmental reasons.

Cost estimates by EPA differ from those above in that the EPA estimates are engineering estimates based on typical or model firms utilizing existing technology. This assumption and method of estimating may result in the overstatement of costs, according to EPA, since they make no allowance for process changes or technological innovation.

The Council on Environmental Quality (CEQ) began a series of estimates with the 1971 annual report. The estimates were based on those of EPA, BEA, the Census, and other sources. The CEQ estimates are disaggregated to reflect private and public expenditures. The estimates differed from all others in that the CEQ estimates reflect annual capital costs (interest and depreciation) rather than the capital expenditures reported in other estimates. The CEQ estimates also include operation and maintenance costs. Another unique feature of the CEQ estimates are the projected cumulative estimates for the coming decade.

Impact Assessment

Macroeconomic studies are said to be the bridge between environmentalists and policymakers. However, the assumptions underlying the assessments may be troublesome. The potential for overstatement of costs is but one area for disagreement. The one-to-one tradeoff between pollution abatement expenditures and business capital expenditures is another. Earlier studies assumed that pollution abatement expenditures caused unemployment; more recent studies, however, suggest a small positive employment increase because of environmental expenditures. The assumption that pollution abatement is non-productive and the lack of benefits assessment are other weakness of macroeconomic studies.

Siting and Delays

Studies sponsored by the National Science Foundation found no credible evidence to support allegations that environmental regulations have or are about to precipitate significant movements of domestic industry to foreign countries. These conclusions, similar to those of earlier studies by the Department of Commerce, the United Nations, and the Organization for Economic Cooperation and Development, suggest that locational factors, political stability, labor costs, and age of production facility are among the factors that exert pressures equal to or exceeding pressure from environmental requirements in the siting of manufacturing facilities.

Benefit-Cost Analysis

The term benefit-cost analysis has become commonplace in the discussion of regulation. Theoretically, the concept is well developed; however, the clamor for benefit-cost solutions remains largely rhetorial primarily because it is impossible to secure a consensus on the monetization of benefits, especially the value of health and life. Variations and uncertainties in estimates of benefits arise from four problem areas in the process: specification; measurement; valuations; and aggregations.

Specification errors stem from the inability to define or account for all important variables and relationships. The lack of observations on variables such as property rights, technology changes, micro-climates, cultural expectations and so on can drastically change the outcome of benefit-cost analyses.

Measurement errors, generally, arise from problems at monitoring locations, averaging and aggregation difficulties, problems in characterization of the population at risk, inability to separate effects of co-factors and other process difficulties.

Valuation errors appear because of the inability to assign acceptable values to certain physical, biological, aesthetic, and psychic effects.

Aggregation errors result from attempts to extrapolate local or regional estimates to national levels or from attempts to derive future values from past and current estimates.

The term benefit-cost analysis has an intrinsic appeal to most people because it suggests sound common sense decisionmaking. However, for the decision-maker benefit-cost analysis is an economic analytical tool. It does not dictate choices or abrogate the authority or responsibility of the decision-maker.

New Economic-Based Techniques for Pollution Control

Concern for economic efficiency in pollution control programs has led to various proposals for incorporating economic-based techniques into the existing regulatory framework. Of these, the most developed is the "bubble," in which diverse sources of a pollutant are treated together.

The bubble policy, as a strategy for air-pollution management, was initiated by EPA in 1975, and revised in 1979 and 1982. The 1975 policy had an intrasource focus that gave managers flexibility to treat total emissions as though they emerged from an imaginary enclosure or bubble. EPA held that this policy was designed to achieve reductions in a less costly manner. The 1979 revision of the policy had an intersource focus, whereby firms could exchange pollution reductions to comply with State Implementation Plans (SIPs). The 1982 revision was broadened to include intersource trading of pollution reductions in non-attainment areas and by non-complying sources. The policy has not been widely accepted. The courts have ruled that bubbles cannot be applied to new facilities or in nonattainment areas.* In addition, the policy has not been supported by some business groups, environmental groups, and air pollution control officials.

---

*On June 25, 1984, the Supreme Court overturned a lower court ruling and upheld EPA's policy allowing bubbling by stationary sources in nonattainment areas. Chevron U.S.A. Inc. v. NRDC, U.S. ____, (Slip Opinion June 25, 1984).

Another technique in use is the imposition of pollution charges. The Superfund tax levies a fee on a stream of feedstocks that contribute to toxic products. The fund provides the means to clean up toxic waste dumps that have been discovered and that will be discovered and to provide compensation for damages and economic losses from spills, releases, and discharges.

A fund is being proposed for reducing sulfur dioxide emissions. The fund would be derived from a sulfur tax or from contributions based on electric power generation. The fund would be used primarily to reimburse utilities for installing equipment to control sulfur dioxide emissions.

Changing Role of Economics

The environmental economic studies undertaken during the past decade have been informative but have not contributed much to the solution of environmental problems. Nonetheless, the studies suggest that more than half of the pollution abatement expenditures are made just to keep the environment from becoming more degraded than it already is. An ever increasing human population and its accompanying production and consumption needs requires an increasing investment to maintain an environmental status quo.

The Council on Environmental Quality estimates of pollution abatement expenditures, in their own assessment, cannot be used to evaluate benefits and costs of specific standards or provisions of the Clean Air Act, the Clean Water Act, or similar legislation because of the high level of aggregation. Data assembled by other agencies, e.g., BEA and Census, and industry reflect purposes other than assessment of benefits and cost and

Furthermore, they often are too inaccurate to assess overall effectiveness of environmental control programs.

Economists and policymakers views on how to encourage economically efficient pollution control have shifted focus. The debate of regulation versus economic taxes to internalize costs has ended with the recognition that the regulatory bases of the Clean Air Act and Clean Water Act are in place. The focus has shifted to looking at ways to supplement the regulatory approach with economic techniques that would add efficiently. This has led to "bubbles," "emissions trading," "netting," and so on, although statutory requirements have constrained their application, as well as the use of benefit-cost analyses of individual regulations.

At the same time, there is renewed interest in taxes, designed to address specific environmental problems. These taxes are to generate funds for cleanup of hazards where liable parties cannot be found, and or to internalize costs. Funds to pay for cleanup include "Superfund," based on a tax on chemical feedstocks, and the proposal of H.R. 3400 to tax electric power. Proposals for taxes to internalize costs include ones to base "Superfund" on fees on hazardous wastes, and H.R. 4483, which would tax sulfur in coal. The primary difference between the two approaches is that the taxes on emissions are designed to raise the cost of pollution and hence encourage firms to change their behavior to reduce discharges, whereas taxes on feedstocks or products are designed to raise money to deal with more-or-less unavoidable consequences of the industrial activity.

At the same time, the focus on discharge control by economists and others has obscured the ultimate goal, expressed in the Clean Water Act as "zero discharge." This is the goal of encouraging nonpolluting or minimally polluting industrial processes that depends on developing changes-in-production processes (CIPP). During the past decade CIPP has increased in importance as a pollution abatement procedure. In 1977 CIPP accounted for 19 percent of total pollution abatement expenditures; CIPP expenditure increased to 28.3 percent of total expenditures in 1981 and increased further to 31.0 percent of total pollution abatement expenditures in 1982.

The 3M Company initiated a low and non-waste program in 1975. This program was called the "Pollution Prevention Pays" (3P) program. It seeks a solution to environmental degradation through:

1. Product reformation;
2. Process modification; and
3. Recovery of waste material for reuse.

In six years the program saved 3M over $97 million while reducing air pollutants by 127,000 tons, water pollutants by 4,150 tons, waste water by 1,179 million gallons, and sludge by 13,500 tons. In addition, the program produced an estimated energy conservation of 1.2 trillion Btu or the equivalent of 228,000 barrels of oil.

Ultimately, then, encouragement of low-and nonpolluting technology programs could conceivably result in great advances in environmental quality while merging environmental goals with other social and economic objectives. The challenge to economists and policymakers is to devise programs that will encourage inherently clean technologies, so this growth can occur in a clean and healthful evironment.

INTRODUCTION

Environmental legislation, as with all human endeavors, involves objectives, assumptions, and data that society or individuals may agree or disagree with, or be totally indifferent to. Thus, the methods of achieving the objectives to protect and enhance the Nation's air quality (Clean Air Act) and to restore the integrity of its waters (Clean Water Act) are subject to diverse views and debates. Each pollution control strategy includes separate articulations of the objective assumptions and each implies its unique interpretation of the data.

The Clean Air Act and the Clean Water Act rely primarily on regulations and enforcement to achieve ambitious schedules associated with quality standards that were established to protect human health and welfare. The regulatory program has achieved notable successes. Nonetheless, there is criticism of the approach and a call for a pricing solution to the problems of pollution. Some critics argue that little progress will be made in attaining or maintaining environmental quality until pollution is recognized as an economic problem and treated as such. They argue that regulation does not assure cost effectiveness or allow for full consideration of marginal costs, markets, efficiency, equity, or even benefits and costs.

Since taking office on January 20, 1981, President Reagan has taken a number of actions as a part of his broad effort to "free the economy."

In his view, freedom means less regulation and more efficiency; so on February 17, 1980, he issued Executive Order 12291. The order calls for development of regulations through a process that adheres to the following:

> (a) Administrative decisions shall be based on adequate information concerning the need for and consequences of proposed government action;
>
> (b) Regulatory action shall not be undertaken unless the potential benefits to society from the regulation outweigh the potential costs to society;
>
> (c) Regulatory objectives shall be chosen to maximize the net benefits to society;
>
> (d) Among alternative approaches to any given regulatory objective, the alternative involving the least net cost to society shall be chosen; and
>
> (e) Agencies shall set regulatory priorities with the aim of maximizing the aggregate net benefits to society, taking into account the condition of the particular industries affected by regulations, the condition of the national economy, and other regulatory actions contemplated for the future. 1/

The Executive order stresses the importance of benefits in promulgating of regulations. This emphasis tends to increase the concern for economic evaluations.

Certainly the framers of the Clean Air Act and the Clean Water Act anticipated the significance of economics in attaining the objectives of these Acts; they mandated the Environmental Protection Agency to make and report detailed estimates of costs of carrying out the Acts. The studies were to identify costs of the programs, the impact of the standards

---

1/ Executive Office of the President. Federal Regulation. Executive Order 12291. February 17, 1981.

on the economy, potential benefits and other economic factors that might facilitate the goals of the Acts.

The objective of this report is to examine recent attempts to establish and improve the economic data base for evaluation of environmental issues. This environmental economic report will focus on studies in four major categories: data on and assessment of pollution control costs; benefit-cost analysis of environmental regulation; some economic techniques incorporated in pollution control; and environmental economic overview.

This report is the third in a series published as committee prints. The first was printed in 1975 and was entitled "The Status of Environmental Economics"; the second committee print was published in 1979 and was entitled "The Status of Environmental Economics: An Update." This precis and the selected appendix materials are not intended as an apology for nor a criticism of individual studies. It is hoped that the reader will be able to determine the role of current environmental economic data for decisionmaking and to assess the possible roles of economic techniques in pollution control.

DATA ON AND ASSESSMENT OF POLLUTION CONTROL COSTS

A. COST SURVEYS

Considering the clamor for the use of economics for pollution control and environmental enhancement, there are surprisingly few comprehensive estimates of past expenditures. The Department of Commerce's Bureau of Economic Analysis and Bureau of the Census conduct annual surveys to estimate costs of pollution control. Similarly, McGraw-Hill, Incorporated, surveys businesses annually to arrive at estimates of pollution abatement expenditures. The American Petroleum Institute (API) annually surveys the pollution control costs of member companies plus members of the National Petroleum Refiners Association. The Environmental Protection Agency (EPA) and the Council on Environmental Quality (CEQ) also develop estimates of pollution control expenditure; however, these estimates are not necessarily developed annually (table 1).

Generally, these studies make no judgments on the value of regulatory efforts; they simply reflect the expenditures for pollution abatement.

Bureau of Economic Analysis

Because of widespread concern for the environment and the significant levels of private and public spending for pollution abatement, the Department of Commerce's Bureau of Economic Analysis began a program in 1973 to estimate environmental control expenditures within the framework of national economic accounts. The treatment of pollution abatement expenditures within this framework permits assessment of pollution abatement

TABLE 1. MAJOR DATA SOURCES ON ENVIRONMENTAL ECONOMICS

	Sponsor	Source of Data	Coverage	Comments
1.	Bureau of Economic Analysis	Survey	annual plant and equipment expenditures	Annual capital for expenditures for pollution abatement broken into end-of-line and changes in plant processes
2.	Bureau of Census	Survey	Probability survey of 20,000 manufacturers	Includes capital expenditures and operation and maintenance
3.	McGraw-Hill	Survey	450 companies	Annual capital expenditures
4.	Council on Environmental Equality	Aggregation	Public and private expenditures	Annual costs (interest and depreciation) Includes O&M; and projects costs into future
5.	Environmental Protection Agency	Engineering estimates	Assumed model firms in industry	Engineering estimates based on assumed application of existing technology
6.	American Petroleum Institute	Survey	National Petroleum Refineries Association and American Petroleum Institute members	Includes costs reported to BEA and other environment expenditures

costs in relation to other components of the Accounts. The BEA estimates are based on questions incorporated in BEA's annual new plant and equipment survey that is mailed to about 10,000 companies. Each company receives one report to supply information for its entire operation. The companies are designated either as manufacturing or nonmanufacturing based on their primary activity.

From its beginning in 1973, BEA's tabulation of pollution abatement expenditures (PAE) has been affected by five major problems in the definition and collection of this data. These problems include:

> 1. The baseline problem. Some forms of pollution abatement have been practiced for decades and therefore it is difficult, if not impossible, to exclude all abatement costs from the production process;
>
> 2. Joint costs. These are costs that arise because abatement techniques may increase productivity or have valuable by-products;
>
> 3. Treatment of capital costs. This problem involves the classification of capital goods acquired to produce goods and services sold to others when it also results in reducing pollution;
>
> 4. Expenditures not recognized as pollution abatement; and
>
> 5. Separation of pollution abatement expenditures from expenditures incurred for related purposes, such as industrial safety. 2/

2/ For a complete discussion of these problems, see: Cremeans, John E. Capital Expenditures by Business for Air and Water Pollution Abatement, 1973 and Planned 1974. Survey of Current Business. July 1974.

Table 2—New Plant and Equipment Expenditures by U.S. Nonfarm Business: Total and for Pollution Abatement

[Billions of dollars]

	1981					1982					Planned 1983				
	Total ¹	Pollution abatement				Total ¹	Pollution abatement				Total ¹	Pollution abatement			
		Total	Air	Water	Solid waste		Total	Air	Water	Solid waste		Total	Air	Water	Solid waste
Total nonfarm business	**321.49**	**8.93**	**4.97**	**3.04**	**0.92**	**316.13**	**8.49**	**4.69**	**2.98**	**0.82**	**319.92**	**8.26**	**4.06**	**3.34**	**0.86**
Manufacturing	**126.79**	**5.42**	**2.69**	**2.10**	**.63**	**119.68**	**4.72**	**2.28**	**1.94**	**.51**	**115.90**	**4.63**	**1.83**	**2.25**	**.56**
Durable goods	**61.84**	**1.97**	**1.09**	**.70**	**.18**	**56.44**	**1.76**	**.92**	**.69**	**.14**	**54.22**	**1.63**	**.80**	**.68**	**.16**
Primary metals ²	8.12	.78	.54	.19	.05	7.46	.76	.45	.27	.03	5.95	.58	.32	.22	.04
Blast furnaces, steel works	3.17	.49	.33	.13	.02	3.47	.41	.21	.19	.01	2.56	.26	.13	.12	.01
Nonferrous metals	3.46	.23	.16	.05	.03	2.71	.30	.20	.08	.02	2.38	.28	.17	.10	.02
Fabricated metals	2.96	.07	.02	.04	(*)	2.59	.04	.02	.02	(*)	2.24	.03	.01	.01	(*)
Electrical machinery	10.31	.18	.08	.07	.02	10.62	.15	.06	.08	.02	10.97	.14	.05	.08	.01
Machinery, except electrical	13.22	.15	.05	.09	.01	12.89	.18	.08	.08	.03	13.12	.20	.08	.08	.03
Transportation equipment ²	18.39	.46	.20	.21	.06	15.16	.40	.21	.16	.03	14.56	.48	.22	.22	.05
Motor vehicles	10.08	.35	.16	.16	.04	7.92	.32	.18	.12	.02	8.05	.39	.19	.18	.02
Aircraft	6.43	.10	.03	.05	.02	6.04	.08	.03	.04	.01	5.55	.09	.03	.04	.02
Stone, clay, and glass	3.14	.16	.12	.03	.01	2.61	.08	.05	.01	.02	2.43	.09	.06	.02	.01
Other durables ³	5.69	.16	.07	.07	.02	5.13	.15	.07	.07	.02	4.84	.12	.05	.06	.01
Nondurable goods	**64.95**	**3.46**	**1.60**	**1.40**	**.45**	**63.23**	**2.96**	**1.36**	**1.25**	**.36**	**61.69**	**3.00**	**1.03**	**1.57**	**.40**
Food including beverage	8.22	.30	.13	.14	.04	7.74	.38	.17	.16	.04	7.46	.33	.14	.15	.04
Textiles	1.56	.05	.03	.02	(*)	1.33	.03	.01	.02	(*)	1.31	.03	.01	.02	(*)
Paper	6.72	.38	.16	.12	.11	5.97	.30	.15	.09	.06	6.09	.43	.17	.16	.09
Chemicals	13.60	.88	.38	.36	.14	13.27	.67	.32	.27	.07	13.69	.54	.21	.26	.06
Petroleum	26.56	1.76	.88	.74	.14	26.69	1.50	.67	.67	.16	24.57	1.59	.46	.95	.18
Rubber	1.77	.04	.02	.02	.01	1.71	.04	.02	.01	.01	1.84	.03	.01	.01	.01
Other nondurables ⁴	6.53	.04	.02	.01	.01	6.52	.04	.02	.01	.01	6.71	.05	.02	.02	.01
Nonmanufacturing	**194.70**	**3.51**	**2.28**	**.94**	**.29**	**196.75**	**3.77**	**2.41**	**1.04**	**.32**	**195.02**	**3.63**	**2.23**	**1.10**	**.30**
Mining	16.86	.46	.18	.18	.10	15.45	.52	.21	.20	.11	15.46	.63	.30	.26	.08
Transportation	12.05	.09	.04	.04	.01	11.95	.14	.08	.05	.01	11.00	.12	.06	.05	.01
Railroad	4.24	.04	.02	.02	(*)	4.38	.08	.05	.03	(*)	4.21	.08	.04	.03	.01
Air	3.81	.01	.01	(*)	(*)	3.93	.01	.01	.00	(*)	3.33	(*)	(*)	.00	(*)
Other	4.00	.05	.02	.02	(*)	3.64	.05	.03	.02	.01	3.46	.04	.01	.02	(*)
Public utilities	38.40	2.80	1.98	.67	.15	41.95	3.00	2.07	.77	.15	41.00	2.76	1.83	.76	.17
Electric	29.74	2.71	1.91	.65	.15	33.40	2.89	2.01	.73	.15	33.09	2.65	1.76	.72	.17
Gas and other	8.65	.09	.06	.03	(*)	8.55	.11	.06	.05	.01	7.91	.11	.07	.04	(*)
Trade and services	86.33	.11	.05	.04	.03	86.95	.09	.04	.02	.03	87.78	.09	.03	.02	.04
Communication and other ⁵	41.06	.03	.02	.01	(*)	40.46	.02	.01	.01	(*)	39.78	.02	.01	(*)	(*)

*Less than $5 million.

1. Consists of final estimates taken from the quarterly surveys of total new plant and equipment and, for 1983, plans based on the survey taken in late January and February 1983.

2. Includes industries not shown separately.

3. Consists of lumber, furniture, instruments, and miscellaneous.

4. Consists of apparel, tobacco, leather, and printing-publishing.

5. Consists of communication; construction; social services and membership organizations; and forestry, fisheries, and agricultural services.

Source: Survey of Current Business. June 1983. p. 25.

Table 3—New Plant and Equipment Expenditures for Pollution Abatement in Current and Constant Dollars with Implicit Price Deflators

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
	Billions of dollars									
Total	4.92	5.70	6.97	7.23	7.34	7.58	8.42	9.20	8.93	8.49
Air	2.92	3.37	4.02	3.81	3.80	3.91	4.50	5.07	4.97	4.69
Water	1.69	1.93	2.56	2.97	3.04	3.11	3.21	3.28	3.04	2.98
Solid waste	.31	.40	.39	.45	.50	.56	.71	.85	.92	.82
	Billions of constant (1972) dollars									
Total	4.67	4.68	5.16	5.09	4.83	4.64	4.69	4.64	4.08	[1] 3.63
Air	2.79	2.74	2.93	2.64	2.46	2.38	2.50	2.54	2.25	1.96
Water	1.58	1.60	1.95	2.14	2.05	1.93	1.81	1.70	1.42	1.33
Solid waste	.30	.34	.29	.32	.33	.33	.38	.41	.40	.34
	Implicit price deflators, 1972=100									
Total	105.5	121.8	135.0	142.0	151.8	163.3	179.6	198.1	219.0	[1] 233.7
Air	105.0	122.6	137.4	144.5	154.6	164.5	180.2	199.6	220.6	238.7
Water	106.5	121.0	131.4	139.0	148.4	161.1	177.2	193.4	213.5	223.7
Solid waste	104.3	118.8	134.4	141.6	152.9	168.0	186.2	208.7	229.8	243.7

[1] The implicit price deflators for 1982 are based on preliminary source data.

Source: Survey of Current Business. June 1983.

BEA has established two classes of abatement expenditures in their studies, "end-of-line" and "changes-in-production-processes." End-of-line (EOL) methods treat pollutants after they are generated; changes-in-production-process (CIPP) methods are preventive, reducing the generation of pollutants and the need for treatment. Three-fourths of the pollution abatement expenditures were for end-of-line methods. The high percentage possibly stems from the rapid response this system provides for meeting environmental-regulatory conditions. CIPP spending, on the other hand, must wait for completion of research and development on specific processes and, often, the construction of new facilities.

According to the latest BEA 3/ survey, business spent about $8.49 billion for air, water, and solid waste pollution abatement in 1982 (table 2). This represents about 2.7 percent of the total expenditures of $316.43 billion for new plant and equipment. Data presented in table 3 show pollution abatement expenditures from 1973 through 1982. Expenditures have declined since 1976 in terms of constant (1972) dollars. The BEA report highlights the decline of EOL spending in 1981 and 1982 and the concommitant increase of CIPP spending during those years. In 1977 the EOL and CIPP expenditures amounted to 81 and 19 percent of total abatement expenditures respectively. In 1981 EOL accounted for 71.44 percent of abatement expenditures while CIPP expenditures reached 28.3 percent of the total. (The CIPP expenditures are derived by subtracting estimates in table 4 from

---

3/ Russo, William J. Jr., and Gary L. Rutledge. Plant and Equipment for Pollution Abatement, 1982 and Planned 1983. Survey of Current Business. June 1983.

those in table 2). EOL treatment in 1982 accounted for $5.86 billion, or 69 percent of the total pollution abatement expenditures, and CIPP expenditures of $2.63 billion accounted for nearly 31 percent of the total abatement expenditures. These trends suggest that regulations can lead to innovations in production techniques to abate pollution.

The major spenders for pollution abatement include six industries: blast furnaces; nonferrous metals; paper; chemicals; petroleum; and electric utilities. These six industries spent $6.07 billion for pollution abatement in 1982, or 71.49 percent of the total U.S. expenditures of $8.49 billion (table 5). Pollution abatement expenditures accounted for nearly 7.1 percent of the total new plant and equipment expenditures for these six industries. The average CIPP expenditures for these industries, percentage-wise, are lower than for industry as a whole, with CIPP accounting for only 27.84 percent of abatement expenditures. However, the paper industry's CIPP expenditures reached 46.66 percent, petroleum 31.33 percent, and nonferrous metals 30.00 percent.

Bureau of Census

The most recent survey by the Bureau of Census was compiled from a probability sample of about 20,000 manufacturing establishments with 20 employees or more that were selected from the 1977 Annual Survey of Manufactures (ASM). The 1977 ASM, was, in turn, a probability sample of about 70,000 establishments selected from a total of 312,000 establishments. All establishments with value of shipments of $30.1 million in the 1977 ASM were included in the survey. Establishments with less than $30.1 million

Table 4.—New Plant and Equipment Expenditures by U.S. Nonfarm Business for Air and Water Pollution Abatement by End-of-Line Methods [1]

[Billion of dollars]

	1981			1982			Planned 1983		
	Total	Air	Water	Total	Air	Water	Total	Air	Water
Total nonfarm business	6.40	4.03	2.37	5.86	3.58	2.28	5.68	3.13	2.55
Manufacturing	3.85	2.17	1.68	3.13	1.58	1.54	3.09	1.33	1.76
Durable goods	1.35	.83	.51	1.21	.66	.56	1.15	.59	.56
Primary metals [2]	.62	.46	.16	.59	.35	.24	.45	.26	.19
Blast furnaces, steel works	.44	.31	.13	.35	.17	.19	.22	.11	.11
Nonferrous metals	.14	.11	.03	.21	.15	.06	.21	.13	.08
Fabricated metals	.04	.01	.03	.02	.01	.01	.02	.01	.01
Electrical machinery	.11	.06	.04	.11	.04	.06	.10	.04	.06
Machinery, except electrical	.11	.03	.08	.13	.06	.07	.12	.05	.08
Transportation equipment [2]	.23	.11	.12	.23	.12	.11	.31	.14	.16
Motor vehicles	.18	.09	.09	.19	.11	.08	.27	.13	.14
Aircraft	.05	.02	.03	.03	.01	.02	.04	.02	.02
Stone, clay, and glass	.12	.10	.02	.05	.04	.01	.05	.04	.01
Other durables [3]	.11	.05	.05	.09	.04	.05	.10	.05	.05
Nondurable goods	2.50	1.34	1.17	1.91	.93	.99	1.94	.74	1.20
Food including beverage	.18	.09	.08	.15	.08	.07	.12	.05	.07
Textiles	.03	.01	.02	.02	.01	.02	.02	.01	.01
Paper	.15	.09	.07	.16	.10	.06	.18	.11	.07
Chemicals	.69	.35	.33	.49	.26	.23	.38	.17	.21
Petroleum	1.40	.77	.63	1.03	.45	.58	1.18	.38	.80
Rubber	.03	.01	.02	.03	.01	.01	.02	.01	.01
Other nondurables [4]	.03	.02	.01	.03	.01	.01	.03	.01	.02
Nonmanufacturing	2.55	1.86	.69	2.73	2.00	.74	2.60	1.80	.80
Mining	.34	.17	.17	.38	.20	.17	.51	.28	.23
Transportation	.07	.04	.03	.11	.07	.04	.10	.05	.05
Railroad	.03	.01	.02	.07	.04	.03	.07	.04	.03
Air	(*)	(*)	.00	(*)	(*)	.00	(*)	(*)	.00
Other	.04	.02	.02	.03	.02	.01	.04	.01	.02
Public utilities	2.06	1.61	.46	2.20	1.70	.50	1.94	1.44	.50
Electric	2.01	1.58	.44	2.15	1.68	.47	1.88	1.41	.47
Gas and other	.05	.03	.02	.05	.02	.03	.07	.04	.03
Trade and services	.06	.03	.03	.04	.02	.02	.03	.01	.02
Communication and other [5]	.02	.02	(*)	.01	.01	(*)	.01	.01	(*)

*Less than $5 million.

1 End-of-line methods involve the separation, treatment, or reuse of pollutants after they are generated but before they are emitted from a company's property. Changes-in-production-process estimates for air and water pollution abatement can be derived by subtracting estimates in this table from those in table 1.

2 Includes industries not shown separately.

3 Consists of lumber, furniture, instruments, and miscellaneous.

4 Consists of apparel, tobacco, leather, and printing-publishing.

5 Consists of communication; construction; social services and membership organizations; and forestry, fisheries, and agricultural services.

Source: Survey of Current Business. June 1983. p. 26.

TABLE 5. NEW PLANT AND EQUIPMENT EXPENDITURES BY SELECTED U.S. NONFARM BUSINESS: TOTAL AND FOR POLLUTION ABATEMENT, 1982

(billions of dollars)

		Pollutation Abatement			
	Total	Total	EOL	CIPP	Percent CIPP of Total Abatement
Blast Furnaces	$3.41	$0.41	$0.35	$0.06	14.63
Nonferrous Metal	2.71	0.30	0.21	0.09	30.00
Paper	5.97	0.30	0.16	0.14	46.66
Chemicals	13.27	0.67	0.49	0.18	26.86
Petroleum	26.69	1.50	1.03	0.47	31.33
Electric Utilities	33.40	2.89	2.15	0.74	25.60
TOTAL	85.51	6.07	4.39	1.68	27.84

Source: Derived from Russo, William J. Jr., op. cit.

were included in the survey. Establishments with less than $30.1 million in value of shipments were assigned probabilities of selection ranging from 0.99 to 0.005. The smaller establishments were arrayed by industry and selected systematically to assure a proportionate representation from each major industry group.

The Bureau of Census survey differs from that of BEA in the types of reporting units used to collect the data. The Census survey is based on a probability sample of 20,000 manufacturing establishments. Capital expenditures at a particular location engaged in manufacture are the only expenditures reported. In contrast, BEA surveys rely on the company as the reporting unit and its entire operation is included; however, the classification is according to the major activity. Thus, a BEA manufacturing classification could include retailing, mining, transportation and service while the Census classification would include only the manufacturing. Table 6 compares the expenditure estimates as developed from the Census and BEA surveys for 1979 to 1981. The Census estimates over the years have ranged from 60 to 75 percent of the BEA estimates because of the manufacturing classification.

One interesting finding of the Census survey is that about one-third of pollution abatement expenditures were in the States of Texas, Pennsylvania, California and Michigan. Chart A shows the capital expenditures by manufacturers for pollution abatement by State.

Table 6 Total New Capital Expenditures and Pollution Abatement Expenditures for New Plant and Equipment—BEA and Census, by Industry Group: 1979 to 1981

(In millions of dollars)

Industry group	Data source	1981					1980					1979				
		TNCE	Pollution abatement expenditures				TNCE	Pollution abatement expenditures				TNCE	Pollution abatement expenditures			
			Total	Air	Water	Solid waste		Total	Air	Water	Solid waste		Total	Air	Water	Solid waste
All manufacturing	BEA	126,790	5,420	2,690	2,100	630	115,810	5,520	2,880	2,090	550	96,680	6,820	2,250	1,840	430
	Census	(NA)	3,485	2,194	1,028	263	70,569	3,503	2,106	1,147	251	61,533	3,565	2,072	1,246	247
Durable goods	BEA	61,840	1,970	1,090	700	180	58,910	2,270	1,420	690	150	51,070	2,000	1,210	650	140
	Census	(NA)	1,587	1,141	358	68	39,608	1,530	1,062	390	77	33,926	1,553	1,040	440	71
Primary metals	BEA	8,120	780	540	190	50	7,710	980	670	260	40	6,760	920	640	260	20
	Census	(NA)	728	567	144	17	5,496	740	540	181	20	r5,129	823	589	227	7
Electrical machinery	BEA	10,310	180	80	70	20	9,590	160	70	60	20	7,280	110	50	60	10
	Census	(NA)	97	49	41	7	7,934	79	44	27	8	4,566	91	42	42	7
Machinery except electrical	BEA	13,220	150	50	90	10	11,590	150	70	70	10	10,520	140	70	60	10
	Census	(NA)	67	31	28	8	6,162	75	34	35	6	6,817	85	39	38	8
Transportation equipment	BEA	18,390	460	200	210	60	18,160	520	310	170	40	15,320	410	190	160	60
	Census	(NA)	283	209	60	14	8,002	275	201	61	13	6,854	190	120	60	10
Stone, clay, and glass	BEA	3,140	160	120	30	10	3,820	250	210	30	10	3,940	210	170	30	10
	Census	(NA)	189	166	14	9	3,039	151	123	18	10	2,606	147	110	25	10
Fabricated metals[2]	BEA	2,960	70	20	40	(*)	2,960	70	20	30	10	7,270	220	110	90	10
	Census	(NA)	76	37	30	8	3,919	77	38	35	4	7,981	217	140	48	29
Other durable[2]	BEA	5,690	160	70	70	20	5,090	140	70	60	10					
	Census	(NA)	147	82	41	25	5,056	133	82	34	16					
Nondurable goods	BEA	64,950	3,460	1,600	1,400	450	56,900	3,250	1,460	1,400	400	47,610	2,820	1,343	1,190	290
	[1]Census	(NA)	1,900	1,052	672	177	30,961	1,976	1,044	760	175	27,607	2,014	1,035	804	177
Food, including beverages	BEA	8,220	300	130	140	40	7,390	270	80	180	20	6,620	270	80	160	30
	Census	(NA)	174	54	105	15	5,852	208	62	133	14	5,034	183	58	111	14
Textiles	BEA	1,560	50	30	20	(*)	1,620	70	50	20	(*)	1,500	60	30	20	(*)
	Census	(NA)	48	27	16	5	1,495	60	33	24	4	1,329	39	22	15	2
Paper	BEA	6,720	380	160	120	110	6,800	390	160	160	70	5,550	400	180	180	50
	Census	(NA)	286	168	87	31	5,213	340	197	111	31	r4,447	426	207	181	39
Chemicals	BEA	13,600	880	380	360	140	12,600	730	320	320	100	10,780	630	290	280	60
	Census	(NA)	753	335	322	96	8,763	781	326	350	105	7,976	771	315	361	96
Petroleum	BEA	26,560	1,760	880	740	140	20,690	1,710	830	690	190	16,210	1,380	720	530	130
	Census	(NA)	591	441	132	18	3,615	532	402	114	15	3,273	534	398	119	17
Rubber	BEA	1,770	40	20	20	10	1,730	40	20	10	10	2,170	60	40	10	10
	Census	(NA)	28	15	6	7	2,087	22	13	7	2	2,208	25	13	9	3
Other nondurables	BEA	6,530	40	20	20	10	6,080	40	10	20	10	4,780	40	10	10	20
	Census	(NA)	20	12	4	5	3,936	33	11	18	4	3,340	36	22	8	6

Note: See text for explanation of differences between BEA and Census estimates.

Totals may not agree with detail because of independent rounding. Census data for pollution abatement expenditures includes only those manufacturing establishments with 20 or more employees; see text.

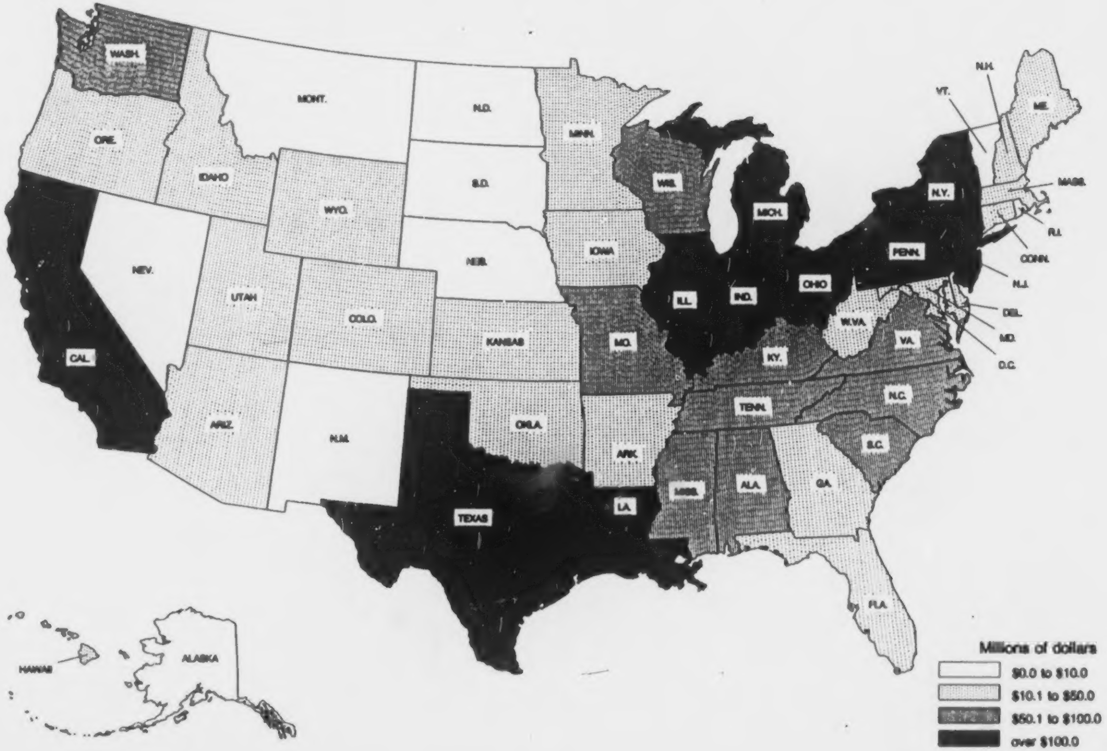
[1] Major industry group 23, Apparel and Other Textile Products, is excluded from all figures except for TNCE from the Annual Survey of Manufactures.

[2] Appears separately for the first time in this report.

Source: U.S. Bureau of the Census, Survey of Pollution Abatement Cost and Expenditures, 1979-1981, Annual Survey of Manufactures 1979-1980, and the U.S. Bureau of Economic Analysis, Plant and Equipment Expenditures, by Business for Pollution Abatement 1973-1981, and Planned 1982, Survey of Current Business, June 1982

CHART A

Capital Expenditures by Manufacturers for Pollution Abatement- By State: 1981


WASH.
ORE.
CAL.
NEV.
IDAHO
MONT.
WYO.
UTAH
ARIZ.
COLO.
N.M.
N.D.
S.D.
NEB.
KANSAS
OKLA.
TEXAS
MINN.
IOWA
MO.
ARK.
LA.
WIS.
ILL.
MICH.
IND.
OHIO
KY.
TENN.
MISS.
ALA.
GA.
FLA.
S.C.
N.C.
VA.
W.VA.
PENN.
N.Y.
VT.
N.H.
ME.
MASS.
R.I.
CONN.
N.J.
DEL.
MD.
D.C.
ALASKA
HAWAII
Millions of dollars
$0.0 to $10.0
$10.1 to $50.0
$50.1 to $100.0
over $100.0

Source: U.S. Bureau of Census. Survey of Pollution Abatement Costs and Expenditures

McGraw-Hill

The 16th Annual McGraw-Hill survey of 450 companies showed that there has been a seven-year decline in pollution abatement spending. McGraw-Hill contends that their estimates represent the spending for the entire industry but the method of extrapolation is not discussed. McGraw-Hill found, as did BEA, that pollution abatement as a share of capital spending declined from a high of 5.6 percent in 1976 to 3.0 percent in 1982 and 2.9 in 1983 (table 7). Two reasons are given for the decline. First, according to the report, the environment is less of a priority for U.S. business 4/ and "... since the election of President Reagan, environmental regulation has ceased to mount." 5/ Second, the report holds that the increase in spending in the early and mid-1970s resulted from bringing plants on line with the newly enacted legislation. Now that the gap has been closed, environmental expenditures will decline in relative importance. A historical summary of pollution abatement expenditures as developed by McGraw-Hill is presented in table 8.

McGraw-Hill reports that planned expenditures during the period 1984-1986 will average about $8.5 billion per year or only about 2.4 percent of all capital spending. The planned expenditures by industry are shown in table 9.

4/ 16th Annual McGraw-Hill Survey of Pollution Control Expenditures, 1983-86. Economics Department. McGraw-Hill Publication Company New York. May, 1983.

5/ Ibid., p. 2

TABLE 7

POLLUTION CONTROL EXPENDITURES AS A PERCENT OF CAPITAL SPENDING--HISTORICAL
(Percent)

INDUSTRY	1967	1968	1969	1970	1971	1972	1973	1974	1975**	1976
Iron & Steel	6.0%	5.2%	8.4%	10.3%	12.8%	12.3%	11.7%	9.3%	14.9%	20.4%
Nonferrous Metals	4.0	1.4	3.7	8.1	10.3	15.3	18.0	28.3	27.5	20.4
Electrical Machinery	1.0	3.0	1.6	2.3	2.3	2.8	3.7	2.3	4.2	4.8
Machinery	1.0	2.1	1.5	3.5	3.4	3.8	4.2	4.1	2.3	4.1
Autos, Trucks & Parts	4.0	2.0	3.3	4.2	6.7	6.6	11.2	10.6	5.7	4.8
Aerospace	1.0	1.9	2.7	2.8	4.7	6.2	10.2	2.0	4.6	4.5
Other Transportation Equipment	2.1	4.4	5.4	5.0	6.2	2.0	4.3	6.4	3.5	4.8
Fabricated Metals	2.0	3.4	3.5	4.3	7.1	7.3	7.2	5.6	10.8	11.2
Instruments	0.9	2.0	3.5	3.6	9.0	3.2	2.9	4.8	5.5	5.5
Stone, Clay & Glass	5.0	4.7	5.9	6.4	13.2	9.6	9.0	17.5	17.6	9.0
Other Durables	4.9	5.0	7.0	9.2	6.4	4.8	6.5	9.0	7.5	6.3
TOTAL DURABLES	2.8	3.1	3.7	5.0	6.3	6.0	7.5	8.4	8.9	8.3
Chemicals	3.0	3.9	4.5	4.9	8.2	10.9	10.2	7.3	8.9	12.3
Paper	6.0	6.2	9.1	9.3	20.6	23.3	22.8	16.6	21.9	25.7
Rubber	1.0	1.0	0.8	5.3	5.4	5.8	6.2	3.0	4.8	5.7
Petroleum	2.0	3.2	4.6	6.0	9.0	10.7	12.7	7.2	12.8	7.5
Food & Beverages	2.0	1.0	2.2	3.0	3.8	5.2	6.3	13.3	5.3	7.3
Textiles	1.0	1.7	1.6	2.3	3.3	2.6	3.5	5.4	8.9	12.6
Other Nondurables	4.0	1.8	2.8	5.5	1.0	5.0	3.1	2.2	1.4	2.2
TOTAL NONDURABLES	2.7	2.9	4.0	5.3	7.3	9.2	9.8	8.4	10.3	10.2
ALL MANUFACTURING	2.8	3.0	3.9	5.1	6.8	7.6	8.9	8.4	9.6	9.3
Mining	4.0	3.4	5.6	6.1	2.8	5.1	7.6	7.0	8.2	6.9
Railroads	NA	NA	NA	1.6	1.2	1.6	2.2	1.9	2.0	1.1
Airlines	NA	NA	NA	0.7	0.7	2.4	9.3	9.2	1.4	1.8
Other Transportation	0.0	0.0	0.0	0.3	5.3	0.8	2.0	2.1	8.6	5.2
Communications	0.0	0.0	0.0	0.0	*	2.4	2.0	4.8	1.4	1.5
Electric Utilities	2.0	2.9	1.7	3.8	4.4	7.9	7.6	7.1	9.1	11.5
Gas Utilities	4.0	1.0	4.9	4.4	2.0	1.6	1.5	2.2	1.3	3.5
Trade & Services	0.0	0.0	0.0	0.6	1.3	1.2	1.3	1.8	1.2	1.3
ALL NONMANUFACTURING	0.6	0.5	0.6	1.2	1.7	2.4	2.9	3.7	3.3	3.7
ALL BUSINESS	1.4	1.4	1.8	2.6	3.3	3.9	4.6	5.3	5.5	5.6

NA - Not Available
* Less than .05%
**Solid waste is included starting in 1975.

TABLE 7

POLLUTION CONTROL EXPENDITURES AS A PERCENT OF CAPITAL SPENDING--HISTORICAL
(Percent)
(Continued)

INDUSTRY	1977	1978	1979	1980	1981
Iron & Steel	16.7%	17.3%	19.9%	15.3%	13.1%
Nonferrous Metals	29.1	12.0	7.6	8.0	6.8
Electrical Machinery	2.7	3.4	2.8	2.1	1.3
Machinery	6.6	3.9	2.2	1.7	2.7
Autos, Trucks & Parts	3.8	4.2	8.4	7.7	1.5
Aerospace	3.3	3.0	1.1	0.5	2.1
Other Transportation Equipment**	3.3	4.2	--	--	--
Fabricated Metals	5.8	5.2	3.9	3.3	2.4
Instruments	3.0	4.0	5.4	3.2	5.6
Stone, Clay & Glass	7.3	8.4	3.6	5.1	5.0
Other Durables	4.9	5.0	4.0	3.3	4.9
TOTAL DURABLES	7.0	5.6	5.0	4.2	3.4
Chemicals	10.5	7.7	6.9	7.6	6.6
Paper	13.0	7.9	7.9	6.7	4.9
Rubber	11.8	5.7	4.7	2.8	3.6
Petroleum	8.3	5.4	7.1	4.2	5.1
Food & Beverages	5.2	6.3	3.3	2.7	4.2
Textiles	6.0	7.8	8.8	5.2	4.9
Other Nondurables	5.1	3.0	2.6	2.9	0.8
TOTAL NONDURABLES	8.7	6.2	6.1	5.0	4.8
ALL MANUFACTURING	7.9	5.9	5.6	4.5	4.1
Mining	17.5	10.7	1.6	1.4	5.8
Railroads	1.8	1.6	1.6	3.7	1.9
Airlines	1.7	1.0	2.8	1.9	*
Other Transportation***	2.3	1.8	--	--	--
Electric Utilities	10.6	8.7	10.7	9.2	9.9
Gas Utilities	3.8	1.3	0.7	*	*
Communications & Trade & Services	1.3	1.5	1.3	0.7	0.2
ALL NONMANUFACTURING	4.3	3.3	2.9	2.1	2.2
ALL BUSINESS	5.5	4.2	3.8	3.1	3.0

NA - Not Available

* Less than 0.5%

** Solid waste is included starting in 1975.

*** As of 1979 other transportation equipment is included in other durables and other transportation services are included with communications and commercial.

TABLE 8

TOTAL POLLUTION CONTROL EXPENDITURES--HISTORICAL
(Millions of Dollars)

INDUSTRY	1967	1968	1969	1970	1971	1972	1973	1974	1975
Iron & Steel	$ 114	$ 105	$ 154	$ 168	$ 163	$ 132	$ 146	$ 180	$ 450
Nonferrous Metals	44	16	39	96	105	148	234	580	597
Electrical Machinery	31	95	52	80	70	79	130	89	132
Machinery	30	61	54	132	107	123	167	214	114
Autos, Trucks & Parts	114	53	99	128	162	198	429	456	191
Aerospace	13	23	35	25	30	42	87	30	77
Other Transportation Equipment	7	15	39	36	30	15	41	67	31
Fabricated Metals	26	46	43	52	85	104	130	109	213
Instruments	6	15	30	31	72	28	33	57	58
Stone, Clay & Glass	46	42	63	68	124	129	142	287	292
Other Durables	64	76	134	177	117	99	164	247	182
TOTAL DURABLES	495	547	742	993	1,065	1,097	1,705	2,316	2,337
Chemicals	92	109	135	166	268	368	432	472	679
Paper & Pulp	89	79	147	162	266	340	454	480	653
Rubber	7	10	9	49	43	60	96	47	56
Petroleum	97	159	242	310	469	513	594	526	1,228
Food & Beverages	41	22	61	100	127	171	228	536	213
Textiles	8	11	14	18	30	28	36	59	80
Other Nondurables	61	28	49	103	20	110	78	53	32
TOTAL NONDURABLES	395	418	657	908	1,223	1,590	1,918	2,173	2,941
ALL MANUFACTURING	890	965	1,399	1,901	2,288	2,687	3,623	4,489	5,278
Mining	55	49	99	108	75	147	252	323	500
Railroads	NA	NA	NA	31	21	27	47	51	58
Airlines	NA	NA	NA	20	10	52	194	178	23
Other Transportation	0	0	0	7	144	23	63	75	360
Communications	0	0	0	*	*	215	422	1,118	305
Electric Utilities	146	231	154	401	540	1,074	1,140	1,181	1,515
Gas Utilities	81	25	130	108	48	43	45	70	43
Trade & Services	0	0	0	179	445	480	592	860	555
ALL NONMANUFACTURING	282	305	383	854	1,283	2,061	2,755	3,856	3,357
ALL BUSINESS	1,172	1,270	1,782	2,755	3,571	4,748	6,378	8,345	8,637

NA - Not Available
* Less than $500,000

TABLE 8

TOTAL POLLUTION CONTROL EXPENDITURES--HISTORICAL
(Millions of Dollars)
(Continued)

INDUSTRY	1976	1977	1978	1979	1980	1981
Iron & Steel	$ 620	$ 466	$ 436	$ 615	$ 503	$ 415
Nonferrous Metals	402	547	253	182	247	234
Electrical Machinery	176	126	193	204	198	132
Machinery	227	435	281	231	200	357
Autos, Trucks & Parts	174	221	303	677	701	150
Aerospace	76	66	97	58	37	138
Other Transportation Equipment**	52	41	66	---	---	---
Fabricated Metals	250	144	150	119	99	70
Instruments	62	41	64	95	72	128
Stone, Clay & Glass	168	164	260	142	193	157
Other Durables	167	146	166	228	202	334
TOTAL DURABLES	2,374	2,397	2,269	2,571	2,452	2,115
Chemicals	999	855	651	744	961	900
Paper & Pulp	799	468	315	438	458	328
Rubber	75	195	120	102	49	63
Petroleum	808	1,053	753	1,151	877	1,355
Food & Beverages	350	266	376	218	200	342
Textiles	132	76	108	132	85	77
Other Nondurables	51	139	103	124	173	55
TOTAL NONDURABLES	3,214	3,052	2,426	2,909	2,803	3,120
ALL MANUFACTURING	5,588	5,449	4,695	5,480	5,255	5,235
Mining	513	1,617	1,092	182	194	983
Railroads	32	55	56	64	158	81
Airlines	21	37	31	112	75	3
Other Transportation**	253	97	74	72	--	--
Communications	352	242	318	309	80	164
Electric Utilities	2,156	2,356	2,143	2,959	2,592	2,956
Gas Utilities	127	173	69	44	*	*
Trade & Services	641	906	1,192	1,158	834	142
ALL NONMANUFACTURING	4,095	5,483	4,975	4,900	3,933	4,329
ALL BUSINESS	9,683	10,932	9,670	10,380	9,188	9,564

NA - Not Available

* Less than $500,000

** As of 1979, other transportation equipment is included in other durables. As of 1980, other transportation services are included with communications.

Council on Environmental Quality

Generally, the Council has developed annual estimates of current and future expenditures for pollution abatement and other measures to protect the environment. The latest was published in the 1980 Eleventh Annual report of the Council. 6/ (The last two CEQ reports, for 1981 and 1982, omitted these cost analyses.) According to CEQ, the estimates serve two purposes, to help determine the macroeconomic impact of Federal environmental regulations, and to provide comparisons with broadscale estimates of benefits associated with regulations.

CEQ does caution the reader that because of the high level of aggregation, its estimates cannot be used to evaluate specific standards or provisions of the Clean Air Act, the Clean Water Act or similar legislation. 7/

The CEQ estimates differ significantly from other estimates, and are much higher. CEQ estimates reflect annual capital costs (interest and depreciation) and not annual capital expenditures. Other differences stem from the estimate of operation and maintenance costs. While the 1979 estimates of BEA, Census and McGraw-Hill were less than $10 billion, CEQ estimates the 1979 annual cost to be $36.9 billion (table 10). CEQ estimates also cover the effects of environmental requirements apparently not considered by other studies, including the Toxic Substances Control Act, Surface Mining Control and Reclamation Act, and others. Furthermore, other surveys

---

6/ Executive Office of the President. Environmental Quality 1980. The Eleventh Annual Report of the Council on Environmental Quality. Washington, D.C. U.S. Government Printing Office. December 1980.

7/ *Ibid*, p. 393.

TABLE 9

INVESTMENT FOR POLLUTION CONTROL
(Millions of Dollars)

INDUSTRY	Actual 1982	Planned 1983	% Change 1982-83	Planned 1984-85 (Annual Average)
Iron & Steel	$ 289	$ 143	-50.5%	$ 248
Nonferrous Metals	219	200	-8.7	251
Electrical Machinery	236	245	3.8	317
Machinery	197	173	-12.2	318
Autos, Trucks & Parts	20	71	255.0	140
Aerospace	128	153	19.5	164
Fabricated Metals	45	62	37.8	50
Instruments	96	127	32.3	262
Stone, Clay & Glass	81	155	91.4	192
Other Durables	154	171	11.0	220
TOTAL DURABLES	1,465	1,500	2.4	2,162
Chemicals	954	794	-16.8	1,268
Paper & Pulp	313	550	75.7	359
Rubber	76	62	-18.4	96
Petroleum	1,252	1,038	-17.1	473
Food & Beverages	530	396	-25.3	370
Textiles	63	70	11.1	70
Other Nondurables	358	591	65.1	339
TOTAL NONDURABLES	3,546	3,501	-1.3	2,975
ALL MANUFACTURING	5,011	5,001	-0.2	5,137
Mining	561	417	-25.7	404
Railroads	184	257	39.7	250
Airlines	140	105	-25.0	75
Electric Utilities	2,889	2,479	-14.2	1,766
Gas Utilities	23	25	8.7	32
Communications & Other	191	170	-11.0	220
Trade & Services	394	499	26.6	620
ALL NONMANUFACTURING	4,382	3,952	-9.8	3,367
ALL BUSINESS	9,393	8,953	-4.9	8,504

Source: 16th Annual McGraw-Hill Survey of Pollution Control Expenditures. May 1983.

Table 10

Estimated Incremental Pollution Abatement Expenditures,[a] 1979–88

(billions of 1979 dollars)

Program	1979			1988			Cumulative (1979–88)		
	Operation and mainte-nance	Annual capital costs[b]	Total annual costs	Operation and mainte-nance	Annual capital costs[b]	Total annual costs	Operation and mainte-nance	Capital costs[b]	Total costs
Air pollution									
Public	1.2	.3	1.5	2.0	.5	2.5	15.8	3.7	19.5
Private									
Mobile	3.2	4.9	8.1	3.7	11.0	14.7	32.1	83.7	115.8
Industrial	2.0	2.3	4.3	3.0	4.1	7.1	25.8	33.0	58.8
Electric utilities	5.5	2.9	8.4	7.6	5.7	13.3	62.3	42.7	105.0
Subtotal	11.9	10.4	22.3	16.3	21.3	37.6	136.0	163.1	299.1
Water Pollution									
Public	1.7	4.3	6.0	3.3	10.0	13.3	25.1	59.2	84.3
Private									
Industrial	3.4	2.6	6.0	5.4	4.5	9.9	42.0	34.0	76.0
Electric utilities	.3	.4	.7	.3	.9	1.2	2.9	6.5	9.4
Subtotal	5.4	7.3	12.7	9.0	15.4	24.4	70.0	99.7	169.7
Solid waste									
Public	<.05	<.05	<.05	.4	.3	.7	2.6	2.0	4.6
Private	<.05	<.05	<.05	.9	.7	1.6	6.4	4.4	10.8
Subtotal	<.05	<.05	<.05	1.3	1.0	2.3	9.0	6.4	15.4
Toxic substances	.1	.2	.3	.5	.6	1.1	3.6	4.6	8.2
Drinking water	<.05	<.05	<.05	.1	.3	.4	1.3	1.4	2.7
Noise	<.05	.1	.1	.6	1.0	1.6	2.6	4.3	6.9
Pesticides	.1	<.05	.1	.1	<.05	.1	1.2	<.05	1.2
Land reclamation	.3	1.1	1.4	.3	1.2	1.5	3.8	11.5	15.3
Total	17.8	19.1	36.9	28.2	40.8	69.0	227.5	291.0	518.5

[a] Incremental costs are those made in response to federal legislation beyond those that would have been made in the absence of that legislation.

[b] Interest and depreciation.

Source: Executive Office of the President. Environmental Quality 1980. The Eleventh Annual Report of the Council on Environmental Quality. Washington, D.C. U.S. Government Printing Office. December 1980. p. 394.

only reflect industry's expenditures, while CEQ's estimates include private and public contributions to pollution abatement.

CEQ cost estimates reflect end-of-the-pipe (equivalent to "end-of-line" as used by BEA) treatment technology and therefore may overstate the true costs. Innovative technology and in-plant process changes that reduce pollutants and recover by-products can reduce the need for enlarging or intensifying end-of-the-line treatment, thereby reducing overall treatment costs.

The CEQ report projects incremental costs--those required by Federal environmental legislation--for 1988 and a cumulative estimate for the 10 year period 1979-1988. The 1988 projection of incremental costs for air pollution is $37.6 billion, and for water pollution is $24.4 billion. Total annual incremental pollution abatement costs are expected to increase to $69.0 billion in 1988. Cumulative 1979-1988 incremental costs for air pollution are estimated at $299.1 billion and $169.7 billion for water pollution. Total cumulative incremental annual costs are expected to amount to $518.5, O&M costs are estimated at $227.5 billion, and capital costs at $291.0 billion.

Another view of pollution control expenditures is presented in table 11. This table reflects total costs, i.e., costs stemming from Federal programs and those resulting from local, regional or State programs. Total abatement costs in 1979 were estimated at $55.9 billion and are projected to increase to $92.9 billion in 1988. Cumulative total abatement costs are projected to reach $735.0 billion for the period 1979-1988.

Table 11

Estimated Total Pollution Abatement Expenditures, 1979–88

(billions of 1979 dollars)

Program	1979			1988			Cumulative (1979–88)		
	Operation and maintenance	Annual capital costs	Total annual costs	Operation and maintenance	Annual capital Costs[a]	Total annual costs	Operation and maintenance	Capital costs	Total costs
Air pollution									
Public	1.7	.4	2.1	2.8	.7	3.5	22.5	5.3	27.8
Private									
Mobile	3.2	4.9	8.1	3.7	11.0	14.7	32.1	83.7	115.8
Industrial	2.5	2.9	5.4	3.9	5.1	9.0	32.5	41.5	74.0
Electric utilities	6.3	3.5	9.8	8.5	6.5	15.0	71.1	50.1	121.2
Subtotal	13.7	11.7	25.4	18.9	23.3	42.2	158.2	180.6	338.8
Water pollution									
Public	3.7	8.2	11.9	5.4	14.2	19.6	45.4	99.7	145.1
Private									
Industrial	4.4	3.2	7.6	6.4	5.1	11.5	52.4	41.1	93.5
Electric utilities	.4	.5	.9	.4	1.1	1.5	3.6	7.8	11.4
Subtotal	8.5	11.9	20.4	12.2	20.4	32.6	101.4	148.6	250.0
Solid waste									
Public	1.7	.3	2.0	2.5	.6	3.1	21.8	5.3	27.1
Private	4.5	.7	5.2	7.5	1.6	9.1	61.3	12.5	73.8
Subtotal	6.2	1.0	7.2	10.0	2.2	12.2	83.1	17.8	100.9
Toxic substances	.1	.2	.3	.5	.6	1.1	3.6	4.6	8.2
Drinking water	.3	.4	.7	.5	.8	1.3	5.3	5.2	10.5
Noise	<.05	.1	.1	.6	1.0	1.6	2.6	4.3	6.9
Pesticides	.1	<.05	.1	.1	<.05	.1	1.6	.1	1.7
Land reclamation	.4	1.3	1.7	.4	1.4	1.8	4.5	13.5	18.0
Total	29.3	26.6	55.9	43.2	49.7	92.9	360.3	374.7	735.0

[a] Interest and depreciation.

Source: Executive Office of the President. Environmental Quality 1980. The Eleventh Annual Report of the Council on Environmental Quality. Washington, D.C. U.S. Government Printing Office. December 1980. p. 397.

The $36.9 billion incremental costs in 1979 represents about 1.5 percent of the gross national product (GNP). The expenditures over the past decade have been about 1 to 2 percent of GNP and it is expected that the projected amounts for 1988 also fall in that range.

Environmental Protection Agency

The Clean Air Act and the Clean Water Act mandated the Administrator of EPA to make and report detailed estimates of the costs of carrying out the respective Acts. The latest report is the 1979, "The Cost of Clean Air and Clean Water." 8/

EPA notes that the estimates are limited to costs associated with Federal regulatory actions resulting from the Clean Air Act and the Clean Water Act. The cost estimates do not account for expenditures incurred voluntarily or required by State and local governments. The reported costs for control of air pollution are, for the most part, based on compliance with Federally-approved State Implementation Plans, New Source Performance Standards, and regulation for mobile sources.

The estimated water pollution control costs are, for the most part, based on compliance with Federal Effluent Limitations Guidelines, New Source Performance Standards, and Pretreatment Standards. Regulation of hazardous and toxic pollutants is also considered.

8/ U.S. Congress. Senate. The Cost of Clean Air and Clean Water. Annual Report of the Administration of the Environmental Protection Agency to the Congress of the United States in Compliance with Section 312(c) of the Clean Air Act, as amended and Section 516(b) of the Federal Water Pollution Control Act Amendments of 1972. Document 96-38, Washington, D.C. U.S. Government Printing Office. December 1979.

The EPA cost estimates differ from other studies in that they are engineering estimates and not developed from industry surveys. The estimates are based on assumed application of existing technology, and are developed to reflect "model plants." Other assumptions include the utilization of average air pollution regulation typical of all State Implementation Plans and making no allowances for process-changes or technological innovation. As such the estimates could result in "overstatement of costs." 9/

The 1977 annualized cost of pollution abatement (air and water) is estimated at $23 billion (table 12) or about 1 percent of the 1977 GNP. The cumulative cost for 1970-1977 was $84.8 billion and the projected cumulative 1977-1986 cost is estimated at about $360 billion.

American Petroleum Institute

The consulting firm Deloitte Haskins and Sells compiled data secured by the American Petroleum Institute (API) in 1980 through a survey of member companies of API and members of the National Petroleum Refiners Association. The companies participating in this survey represented approximately 70 percent of the total industry refinining capacity. The tenth annual report shows a four-fold increase in expenditures from 1970 to 1979. Total expenditures, according to the report, amounted to $2.8 billion in 1979 (table 13). 10/

9/ Ibid., p. iv.

10/ Environmental Expenditures of the United States Petroleum Industry 1970-1979. Pubication no. 4325, Compiled by Deloitte Haskins and Sells. American Petroleum Institute. Washington, D.C.

TABLE 12. COST OF AIR AND WATER POLLUTION CONTROL (IN MILLIONS OF 1977 DOLLARS)

			INVESTMENT	
	1977	1970–77	1977–81	1977–86
COSTS TO GOVERNMENT	5065.00	21593.00	19677.00	45882.00
FUELS & ENERGY				
COAL MINING & COAL CLEANING	22.13	128.73	16.25	30.34
OIL & GAS EXTRACTION & PROCESSING	563.95	912.26	383.18	779.43
PETROLEUM REFINING	902.91	3321.15	1062.52	1326.76
ELECTRIC UTILITIES	3877.70	13127.70	11051.73	20913.55
COAL GASIFICATION	0.0	0.0	70.44	412.03
SUBTOTAL	5366.69	17489.84	12584.12	23462.11
MOBILE SOURCES	2912.00	12050.09	17234.55	49051.55
FOOD PROCESSING				
FEEDLOTS & MEAT PROCESSING	36.52	122.74	159.82	241.12
OTHER FOOD PROCESSING	689.60	4153.08	991.06	2116.23
SUBTOTAL	726.12	4275.82	1150.88	2357.35
CHEMICALS				
BASIC INORGANIC CHEMICALS	254.33	989.21	524.83	875.01
ORGANIC CHEMICALS	1009.65	2060.90	1449.64	2947.17
AGRICULTURAL CHEMICALS	125.24	270.10	152.87	276.04
FORMULATED CHEMICALS	258.38	711.21	1357.15	2129.50
SUBTOTAL	1647.61	4031.41	3484.49	6227.71
CONSTRUCTION MATERIALS	101.70	677.90	198.47	312.25
METALS				
ORE MINING & DRESSING	152.50	389.59	251.00	251.00
IRON & STEEL	981.22	2668.26	2337.60	3613.98
ALUMINUM	71.34	400.35	147.07	410.12
COPPER	90.00	1094.00	171.70	986.00
NONFERROUS METALS, FERROALLOYS, & FOUNDRIES	69.42	731.88	63.05	15091
SUBTOTAL	1364.49	5284.08	2970.42	5412.01
SOFTGOODS				
PULP & PAPER	964.00	3099.75	870.75	1953.05
TEXTILES	24.21	87.84	1030.21	1410.16
LEATHER & RUBBER	82.93	198.40	121.20	181.72
SUBTOTAL	1071.13	3385.99	2022.16	3544.92
MANUFACTURING				
ELECTROPLATING	49.79	264.74	81.55	81.55
SURFACE COATINGS	0.0	0.0	658.82	1707.64
FURNITURE MANUFACTURING	0.0	0.0	2.80	4.80
SUBTOTAL	49.79	264.74	743.17	1793.99
SERVICES				
DRYCLEANING	10.04	141.75	6.75	13.27
HOSPITALS	24.50	69.77	25.65	69.56
PHOTOGRAPHIC PROCESSING	6.21	14.47	5.59	15.69
SUBTOTAL	40.75	225.99	38.00	98.53
WASTE DISPOSAL				
OPEN DUMPS & OPEN BURNING	145.33	1744.12	718.62	2023.34
MUNICIPAL WASTE INCINERATION	4.29	27.11	11.31	24.72
SUBTOTAL	149.62	1771.23	729.93	2048.06
OTHER INDUSTRIAL COSTS				
INDUSTRIAL & COMMERCIAL HEATING BOILERS	238.11	1970.21	268.26	465.11
INDUSTRIAL, COMMERCIAL & BLDG. INCINERATORS	57.02	256.61	275.62	693.80
SUBTOTAL	295.13	2226.82	543.88	1158.92
TOTAL	18790.21	73276.93	61376.92	141349.24

Source: The Cost of Clean Air and Clean Water.

TABLE 12. COST OF AIR AND WATER POLLUTION CONTROL (IN MILLIONS OF 1977 DOLLARS) Continued

		ANNUAL COSTS		
	1977	1970–77	1977–81	1977–86
COSTS TO GOVERNMENT	4588.00	12300.90	25130.00	71720.00
FUELS & ENERGY				
COAL MINING & COAL CLEANING	69.44	212.23	280.07	677.45
OIL & GAS EXTRACTION & PROCESSING	1453.15	3835.18	6289.13	15079.90
PETROLEUM REFINING	638.69	1643.40	3279.71	8268.68
ELECTRIC UTILITIES	4828.77	11372.57	31215.88	82319.19
COAL GASIFICATION	0.0	0.0	174.18	1919.48
SUBTOTAL	5945.70	13913.07	36783.56	97832.44
MOBILE SOURCES	5850.74	38203.01	33146.74	92068.00
FOOD PROCESSING				
FEEDLOTS & MEAT PROCESSING	39.08	98.90	293.18	947.35
OTHER FOOD PROCESSING	1453.15	3835.18	6289.13	15078.90
SUBTOTAL	1492.23	3934.08	6582.31	16027.25
CHEMICALS				
BASIC INORGANIC CHEMICALS	276.35	747.94	1469.03	3935.04
ORGANIC CHEMICALS	421.24	791.90	2589.27	7019.09
AGRICULTURAL CHEMICALS	117.50	223.86	601.37	1667.98
FORMULATED CHEMICALS	146.73	313.65	1070.45	3381.43
SUBTOTAL	961.82	2077.34	5730.12	16003.51
CONSTRUCTION MATERIALS	235.21	718.73	1094.42	2524.83
METALS				
ORE MINING & DRESSING	84.58	145.97	603.18	1340.06
IRON & STEEL	1075.86	3312.17	6595.23	18705.79
ALUMINUM	111.27	352.13	526.92	1236.31
COPPER	199.25	802.96	1011.18	2549.96
NONFERROUS METALS, FERROALLOYS, & FOUNDRIES	198.40	779.70	832.68	1820.02
SUBTOTAL	1669.37	5392.93	9569.18	25652.12
SOFTGOODS				
PULP & PAPER	659.01	1416.82	3014..17	8215.19
TEXTILES	27.42	64.01	1089.87	4499.59
LEATHER & RUBBER	47.68	95.93	254.54	707.69
SUBTOTAL	734.11	1576.76	4358.78	13422.47
MANUFACTURING				
ELECTROPLATING	141.74	316.31	751.27	1771.01
SURFACE COATINGS	0.0	0.0	374.38	1858.20
FURNITURE MANUFACTURING	0.0	0.0	1.37	12.59
SUBTOTAL	141.74	316.31	1127.02	3641.80
SERVICES				
DRYCLEANING	23.07	86.06	95.58	156.53
HOSPITALS	16.37	34.69	79.65	219.62
PHOTOGRAPHIC PROCESSING	4.46	8.45	21.99	59.67
SUBTOTAL	43.90	129.21	197.22	435.81
WASTE DISPOSAL				
OPEN DUMPS & OPEN BURNING	1112.22	4762.36	5419.23	15076.59
MUNICIPAL WASTE INCINERATION	6.05	24.19	30.57	75.14
SUBTOTAL	1118.27	4786.55	5449.80	15151.73
OTHER INDUSTRIAL COSTS				
INDUSTRIAL & COMMERCIAL HEATING BOILERS	349.02	1189.57	1547.50	3634.55
INDUSTRIAL, COMMERCIAL & BLDG. INCINERATORS	93.09	270.33	596.43	2013.17
SUBTOTAL	442.11	1459.90	2143.93	5647.71
TOTAL	23223.21	84808.80	131313.08	360127.75

TABLE 13
SUMMARY TABULATION
(Millions of Dollars)

	YEAR										
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	TOTAL
TABLE II — TOTAL EXPENDITURES											
1. Air	$320	$571	$550	$737	$932	$1.039	$1.216	$1.188	$1,349	$1.616	$9.518
2. Water	259	415	379	402	530	629	822	950	884	1.001	6.271
3. Land and other	60	101	91	100	150	456	336	383	194	203	2.074
TOTAL	$639	$1.087	$1.020	$1,239	$1.612	$2.124	$2.374	$2.521	$2.427	$2.820	$17.863
TABLE III — CAPITAL EXPENDITURES											
1. Air	$181	$391	$305	$436	$527	$601	$536	$339	$429	$561	$4.306
2. Water	163	224	184	194	271	356	411	434	340	394	2,971
3. Land and other	34	57	51	52	97	396	269	184	89	92	1.321
TOTAL	$378	$672	$540	$682	$895	$1.353	$1.216	$957	$858	$1.047	$8.598
TABLE IV — ADMINISTRATIVE, OPERATING, AND MAINTENANCE EXPENDITURES											
1. Air	$108	$143	$ 198	$ 251	$ 352	$389	$635	$792	$864	$997	$ 4,729
2. Water	92	185	187	201	249	262	401	502	532	594	3,205
3. Land and other	24	41	37	43	50	55	63	197	101	106	717
TOTAL	$224	$369	$422	$495	$651	$706	$1,099	$1,491	$1,497	$1,697	$ 8,651
TABLE V — RESEARCH AND DEVELOPMENT EXPENDITURES											
1. Air	$ 31	$ 37	$ 47	$ 50	$ 53	$ 49	$ 45	$ 57	$ 56	$ 58	$483
2. Water	4	6	8	7	10	11	10	14	12	13	95
3. Land and other	2	3	3	5	3	5	4	2	4	5	36
TOTAL	$ 37	$ 46	$ 58	$ 62	$ 66	$ 65	$ 59	$ 73	$ 72	$ 76	$614

Source: Environmental Expenditures of the United States Petroleum Industry 1970-1979. Publication No. 4325. Compiled by Deloitte Haskins and Sells. American Petroleum Institute. Washington, D.C. 1980.

The API survey differs from others in that it goes beyond Federal environmental regulations. Participants were asked to report expenditures related to prevention, control, abatement, or elimination of environmental pollution, including expenditures to meet Federal, State or local regulatory requirements or those to meet tax relief provisions and those that qualify for industrial revenue bonding. Participants were asked to report not only "pollution abatement" expenditures reported to the Bureau of Census and the Bureau of Economic Analysis, but also those expenditures to modify products for environmental reasons.

SUMMARY

The cost estimates of the six major data sources are all different. The BEA estimates are industry annual capital expenditures estimates developed from a survey of 10,000 companies. The data are categorized as manufacturing or nonmanufacturing according to the major primary activity. Thus estimates for a manufacturing firm may include expenditures associated with transporation or other activities.

The Census estimates are annual capital expenditures based on a survey of about 20,000 manufacturing plants; the McGraw-Hill estimates are based on a survey of 450 companies.

The CEQ estimates are largely synthesized from estimates of EPA, and as such are engineering estimates based on assumed levels of control. They include private and public annual capital costs.

The EPA engineering estimates are based on typical or model firms utilizing existing technology. This method may fall short in that it may not reflect economies of size and locational advantages of firms.

The API estimates include expenditures for pollution abatement and any expenditure to modify products for environmental reasons.

The studies all indicate that pollution abatement expenditures as a percent of total plant and equipment expenditures are down from earlier years. Similarly, the expenditure as a percent of GNP appears to be decreasing. Studies by the Bureau of Economic Analysis suggest that industries, adjustment to environmental requirements tend to incorporate changes-in-plant-processes for end-of-the-line treatment. This should reduce abatement costs in the future.

EPA and CEQ have, in the past, provided and maintained environmental economic data bases; however, there appears to be a break in the series. EPA is required to report to Congress annually on the Cost of Clean Air and the Cost of Clean Water. The latest report was in 1979. The Council on Environmental Quality had reported its annual series on incremental and total costs each year in the annual report. These data, however, have been absent from the 1981 and 1982 annual reports. It appears incongruous, that with concern about economic impacts so high, that these series have not been continued.

B. IMPACT ASSESSMENT

Not everyone is satisfied that the cost studies provide a satisfactory picture of the impact of environmental expenditures. These critics believe that the environmental expenditures reduce the amount of capital available for productive purposes, thereby reducing the gross national product, employment, and investments; and cause inflation. CEQ and/or EPA have periodically sponsored studies that address macroeconomic impacts of environmental programs. These studies attempt to establish relationships between environmental expenditures and other national objectives. The most recent study was sponsored by EPA and was undertaken by Data Resources, Incorporated.

Other studies discussed below include the analysis of other various attempts to measure the impacts of environmental expenditures. They vary significantly in scope. A Study by Putnam, Hayes and Bartlett, a consulting firm, discussed on page 48, is concerned only with the accuracy of pollution control cost estimates. The Public Interest Economics Foundation study discussed on page 53, is concerned only with the impacts of the Clean Air Act expenditures on the economy. However, the BEA study, discussed on page 50, is concerned with the impacts on productivity of all environmental expenditures.

Data Resources Incorporated

On July 14, 1981, Data Resources, Inc. (DRI) released a study of the macroeconomic impact of Federal pollution control programs on the economy. 11/ This analysis updated a previous study completed in 1979. The recent analysis used the DRI macroeconomic model of the U.S. economy and covered the period 1970-1987. The analysis compared the economic conditions that would have existed without the cost of Federal regulations to the economic conditions existing with the costs of Federal regulations being imposed on the Nation. The baseline simulation reflects the performance of the economy under current EPA regulations and is

---

11/ The Macroeconomic Impact of Federal Pollution Control Programs: 1981 Assessment. A report submitted to the Environmental Protection Agency. Data Resources, Inc. July 14, 1981.

based on actual 1970-1980 data. The baseline simulation is called the "with" pollution cost scenario. The "without" scenario is a simulation reflecting the removal of incremental costs of Federal pollution control. The comparison of the "with" and "without" simulations gives an assessment of the direct and indirect macroeconomic effects on the economy of federally induced pollution control costs.

The DRI model makes no attempt to measure benefits of pollution control or to estimate technology forcing components of environmental regulations. Thus, the model tends to emphasize the negative impacts of environmental programs while leaving the positive or productive contribution to the economy unaccounted for.

The estimates of incremental pollution control costs were made by EPA. The historical estimates are consistent with estimates collected and developed by the Census Bureau of the Department of Commerce. The incremental pollution control costs include only those resulting from Federal air and water pollution control requirements. The estimates include 16 industrial categories, a State and local municipal waste water treatment facilities category, and a mobile source emissions category. Table 14 presents the estimates of incremental operating and maintenance costs for pollution control for the period 1970 to 1987. The O & M costs increase from $3 billion in 1970 to $24 billion in 1987, an increase of about 13 pecent per year. Total incremental investment increased from $3 billion in 1970 to $20 billion in 1987 (table 15), an increase of about 11 percent per year. The incremental

Table 14
Estimated Incremental Operating and Maintenance Costs For Pollution Control, 1970-1987
(Millions of 1979 dollars)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
TOTAL	3023	4395	6236	8672	9531	9965	10544	11375	12299	13579	14587	15936	17300	18329	20140	21625	23093	24830
All Indus.	959	1349	1864	2612	3386	4134	4944	5729	6489	7440	8409	9492	10812	12204	13768	15440	17114	18789
Mfg. Indus.	406	762	986	1403	1836	2302	2841	3311	3753	4270	4788	5305	6144	6931	7831	8805	9791	10770
Primary Metals	169	210	265	349	438	519	674	789	898	996	1101	1232	1379	1524	1684	1836	1980	2119
Elec. Machinery	3	6	10	18	25	32	37	42	47	71	91	114	146	181	224	275	334	398
Non-elec. Mach.	4	6	9	15	22	29	34	40	45	62	75	90	107	122	140	165	186	207
Transp. Equip.	4	16	31	51	72	91	102	113	123	162	206	265	343	436	545	670	794	917
Stone, Clay, Glass	1	12	26	48	71	101	123	134	144	163	181	202	231	270	315	368	424	484
Oth. Durables	7	18	35	62	92	130	160	181	200	237	270	310	357	413	476	547	615	682
Food incl. Beverage	9	24	43	68	94	117	135	156	177	196	212	229	249	272	300	335	371	412
Textiles	6	8	10	14	17	20	24	29	34	37	40	43	49	57	65	76	88	98
Paper	6	35	72	122	173	242	322	372	420	448	484	520	556	604	651	698	745	791
Chemical	177	213	257	315	374	450	552	671	785	852	905	963	1116	1270	1478	1726	1990	2249
Petroleum	96	148	220	328	441	527	648	747	837	993	1159	1343	1526	1681	1833	1969	2102	2237
Rubber	2	3	3	5	6	9	11	13	15	21	27	33	40	47	56	66	78	89
Oth. Nondurables	2	3	5	8	11	15	19	24	28	32	37	41	45	54	64	74	84	92
Nonmanufacturing	473	674	878	1209	1550	1832	2103	2418	2736	3170	3639	4107	4668	5273	5937	6635	7323	8019
Mining	54	60	69	81	92	95	102	111	116	132	148	165	184	203	224	245	268	290
Public Utilities	400	540	727	997	1276	1537	1780	2066	2359	2755	3189	3615	4119	4667	5271	5910	6537	7172
Commercial	19	47	82	131	182	200	221	241	261	283	302	327	365	403	442	480	518	557
State and Local Govt.	0	27	61	100	175	284	398	537	692	832	983	1134	1268	1380	1486	1583	1672	1752
Mobile Source Controls	2064	3019	4311	5910	5970	5547	5202	5109	5118	5307	5195	5310	5220	4745	4886	4602	4307	4289

Source: The Macroeconomic Impact of Federal Pollution Control Programs: 1981 Assessment. Data Resources, Inc. July 14, 1981. p. 16.

Table 15
Estimated Incremental Investment For Pollution Control, 1970-1987
(Millions of 1979 dollars)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
TOTAL	3375	5086	6558	7524	8418	10308	11745	11631	13036	13536	15641	19142	18787	20131	20366	20409	20369	20029
All Indus.	2872	3807	5480	5665	5422	6054	5779	5574	6760	7019	7573	9404	9898	11087	11811	11905	11908	11627
Mfg. Indus.	1694	2256	3272	3385	3613	4290	3733	3521	3951	3977	4541	5747	5960	6785	7332	7440	7402	7169
Primary Metals	314	422	650	686	772	1042	880	840	752	811	1010	1131	1110	1235	1168	1108	1066	1010
Elec. Machinery	16	26	41	42	40	27	29	26	130	114	126	177	194	240	285	328	354	309
Non-elec. Mach.	12	22	41	43	46	35	40	36	111	88	97	114	100	125	161	145	140	142
Transp. Equip.	69	88	120	124	110	63	65	62	224	261	350	455	546	644	734	728	728	760
Stone, Clay, Glass	89	118	183	195	249	183	88	82	164	145	176	245	327	369	442	470	499	459
Oth. Durables	55	84	139	146	190	152	106	96	181	166	199	215	281	317	355	338	336	343
Food incl. Beverage	137	174	230	234	206	162	196	188	172	148	150	188	209	251	321	323	375	386
Textiles	19	25	32	32	30	42	50	48	29	31	36	51	81	84	112	113	108	105
Paper	243	310	416	424	569	668	419	396	239	297	300	300	397	394	393	390	308	305
Chemicals	293	372	485	491	626	857	890	945	565	440	476	1291	1284	1732	2066	2196	2162	2274
Petroleum	436	598	903	935	720	1010	820	757	1294	1385	1536	1521	1293	1267	1134	1110	1081	921
Rubber	2	6	13	14	32	18	21	20	58	62	58	68	78	88	96	76	56	55
Oth. Nondurables	11	13	19	20	26	30	28	27	32	29	27	31	60	64	65	65	59	50
Nonmanufacturing	1178	1551	2207	2280	1809	1764	2046	2051	2809	3042	3032	3157	3638	4099	4529	4465	4506	4458
Mining	69	88	115	115	28	74	83	57	152	167	171	186	194	203	215	224	220	216
Public Utilities	876	1167	1687	1743	1634	1516	1790	1833	2472	2715	2658	3151	3426	3776	3994	3921	3964	3920
Commercial	234	296	407	422	147	175	172	164	185	160	203	320	318	320	320	320	322	322
State and Local Govt.	-32	573	362	167	1610	1809	3079	2699	2844	2831	2838	2530	2024	1961	1340	1252	1160	1044
Mobile Source Controls	535	706	716	1692	1306	2445	2087	3360	3412	3686	5230	7208	6865	7083	7215	7252	7301	7358

Source: The Macroeconomic Impact of Federal Pollution Control Programs: 1981 Assessment: Data Resources, Inc. July 14, 1981. p. 17.

investment represents about 1.5 percent of total plant and equipment in 1970, 3.9 percent in 1984 and 3.4 percent in 1987. 12/

The changes made to the "with" scenario to remove the incremental Federal pollution control costs include the following:

1. Plant and equipment investment by industry was decreased by the amount of the incremental investment costs estimated by EPA;

2. The cost of new investment was lowered as firms now need to invest less to produce a given amount of output;

3. Since many pollution control investments can be financed less expensively in municipal bond markets, financing costs were raised slightly;

4. Prices by industry were reduced to reflect decreased production costs, as less labor and material are needed to produce a given level of output. These reduced costs were passed through into lower produce prices according to a simple model of industrial price determination constructed for this study;

5. Employment was reduced since the workers required to produce, install and maintain pollution control plant and equipment would no longer be needed;

6. As the Federal Government makes grant-in-aid to state and local governments to construct municipal waste water pollution control facilities, grants-in-aid were reduced by amounts estimated by the EPA;

7. Prices of new motor vehicles were reduced to incorporate the reduced costs of emission control devices;

8. Investment by firms to purchase new vehicles was reduced to reflect the reduced costs of emission control devices;

12/ Ibid., p. 6.

9. Consumer expenditures for vehicle maintenance were reduced to incorporate the lower costs for maintaining emission control devices; and
10. Consumer expenditures for gasoline were reduced as vehicles would achieve higher mileage without emission control devices. 13/

According to the DRI analysis, Federal pollution control regulations have four major effects on the economy.

1. Inflation

   Price increases are moderately higher. The costs per unit of output are raised by the federal regulations and these higher costs are eventually translated into higher prices. For example, the average annual rate of increase in the consumer price index (CPI-U) is 0.4 percentage points higher over the period 1970-1987 than would be the case in the absence of environmental regulations. The average annual rates of increase in the Producer Price Index (PPI) and GNP deflator are 0.5 and 0.4 percentage points higher, respectively, over the same period.

2. GNP

   Until 1977, the real level of economic activity, as measured by gross national product, is stimulated by the incremental investment required under Federal regulations and the additional activity generated by industries producing pollution control plant and equipment. In 1972, real GNP increases $9.2 billion, or 0.5%. After 1979, the real level of economic activity declines as the higher price level reduces aggregate real output. Over the period 1970-1987, the average annual rate of growth of real GNP is reduced by 0.1 percentage point. Real GNP in 1987 is $21.8 billion, or 0.7% lower.

13/ Ibid., p. 8.

3. Employment

   Employment is stimulated throughout the 1970-1987 period. Jobs are created in the pollution control equipment industry and in all industries to operate and maintain pollution equipment and facilities. Unemployment is on average 0.3 percentage points lower over the period. By 1987, there is a net increase of 524,000 additional jobs as a result of pollution controls.

4. Investment

   Real business fixed investment is stimulated by the incremental investment mandated under Federal regulation and by the additional activity generated by industries producing pollution control plant and equipment. In 1973, real business fixed investment is up $6.0 billion, or 2.6%. Eventually, the combined effects of higher prices, increased interest costs, and reduced aggregate demand dampen investment spending. By 1987, real business fixed investment is only $0.9 billion, or 0.3% higher. 14/

Thus, according to DRI, compliance with environmental regulations is predicted to exacerbate inflation, reduce the growth of productivity and income, and stimulate employment throughout the period.

The reader should note that the outcome of macroeconomic studies are sensitive to the assumptions that underdue the calculations. Thus, negative assumptions will result in showing environmental policy as the scapegoat for other social and economic ills. As summarized by Lester Lave and Gilbert Omenn:

14/ Ibid., p. 2-3.

> Troubled industries, such as steel and autos, have laid inordinate blame on environmental policy. Slower productivity increases and anemic investment have been ascribed to environmental policy. In fact, environmental policy is little more than an irritant in the larger social context of an economy that has been plagued by inflation and slow growth. 15/

Putnam, Hayes and Bartlett, Inc.

For every major regulation, EPA has routinely developed estimates of pollution control costs and their economic impact. These estimates have been an issue of intense and controversy to both the government and industry. The objective of a study by Putnam, Hayes, and Bartlett, Inc. (a consulting firm; hereafter referred to as the Putnam study) was to compare estimates of pollution abatement with reported expenditures. The Putnam study compared actual capital expenditures to meet EPA regulations with cost estimates prepared during the development of the regulations for the following six industries:

- o Steam Electric Utilities -- BPT effluent guidelines (BPT means Best Practicable Technology)
- o Electric Utility Flue Gas Desulfurization Systems -- Scrubbers
- o Pulp and Paper -- BPT effluent guidelines
- o Petroleum Refining -- BPT effluent guidelines
- o Iron and Steel -- BPT effluent guidelines

15/ Lave, Lester B., and Gilbert S. Omenn. Clearing The Air: Reforming The Clean Air Act. The Brookings Institution. Washington, D.C. 1981. pp. 44-45.

- Automobiles -- Light duty vehicle air pollution controls. 16/

The Putnam study found through comparison of expenditure forecasts with actual figures that EPA estimates were lower than industry estimates for four of the five industries (table 16). A number greater than 1 means the estimate exceeded the actual cost of compliance. Both EPA and industry estimates tend to overstate compliance costs more often than they underestimate them. For example, EPA forecasts (excluding the forecasts from EPA's reports "The Cost of Clean Air and Water") range from 26 percent below to 156 percent above the reported expenditures, while industry forecasts range from 25 percent below to 247 percent above the reported expenditures. The "Cost of Clean" forecasts ranged from 45 percent below to 84 percent above the actual reported expenditures.

Comparison of estimates of automobile pollution control price increases with actual sticker price increases indicated that EPA estimates are closer than industry estimates to the actual price increases (table 17). Furthermore, industry estimates displayed a large degree of variation.

Putnam reports that the differences in forecasts result from a combination of different assumptions regarding unit control costs, the amount of capacity affected, the industrial growth rate, and the assumed rate of implementation of the program.

16/ Comparisons of Estimated and Actual Pollution Control Cost for Selected Industries. Prepared for the Office of Planning and Evaluation, U.S. Environmental Protection Agency. Prepared by Putnam, Hayes and Bartlett, Inc. February 1980.

Bureau of Economic Analysis

The January 1978 issue of the Survey of Current Business discussed estimates of the effect of pollution controls on productivity for the 1967-75 period. 17/ This study was later extended to include the years 1975-1978. As with the earlier study, the recent analysis explains that the purpose of the estimates is to aid analysis of growth and productivity; it is not to judge the wisdom of Government programs, which have benefits as well as costs." 18/ /

The author assumed that when environmental protection costs are borne by the consumer or the Government, the diversion of expenditures or inputs to environmental protection do not reduce measured input per unit of output. However, when environmental protection costs are incurred by business, the diversions of inputs lowers output per unit of input below what it would have been in the absence of the diversion.

The 1975-78 estimates show that increasing costs of environmental programs continue to cut into the growth rate of output per unit of input by less than a tenth of one percent. Denison reports "the most interesting finding is that the size of the deduction from the annual growth rate, which has climbed to 0.22 percentage points in 1973-75, fell back to 0.08 percentage points in 1975-78." 19/ Denison explains that

---

17/ Denison, Edward F. Effects of Selected Changes in the Institutional and Human Environment Upon Output Per Unit of Input. Survey of Current Business. Vol. 58, No. 1, January 1978. pp. 21-44.

18/ Denison, Edward F. Pollution Abatement Programs: Estimates of Their Effect Upon Output Per Unit of Input, 1975-78. Survey of Current Business. Vol. 59. No. 8. Part 1. pp. 58-59.

19/ Denison. Ibid., p. 58.

TABLE 16

RATIO OF EXPENDITURE
FORECASTS TO ACTUAL EXPENDITURES[1,2]

Expenditure Forecasts	1974-1977	1975-1977	1972-1977
Utilities (BPT Guidelines)			
EPA	.89-.91		
Industry	1.36-1.40		
Electric Utility Scrubbers[3]			
EPA	.74		
Industry	.91		
Pulp and Paper (BPT Guidelines)			
EPA	1.27-1.49		
Cost of Clean[4]			1.14
Industry			.75
Refineries (BPT Guidelines)			
EPA	1.87-2.5		
Cost of Clean[4]			1.82-1.84
Industry	1.91-2.62		
Iron and Steel (BPT Guidelines)			
EPA		1.32-1.79	
Cost of Clean[4]			.55- .85
Industry		2.56-3.47	

---

[1] These ratios are forecasted expenditures divided by actual expenditures.

[2] The range of values reflects comparisons with several expenditure surveys.

[3] These are composite figures representing comparisons including scrubbers installed on new units and scrubbers retrofitted on existing units on a 21 plant sample. (See Section II for more details.)

[4] The Cost of Clean Air and Water, Report to Congress, August 1979.

Source: Putnam Ibid.

TABLE 17

RATIO OF ESTIMATED TO ACTUAL STICKER PRICE INCREASES

	ACTUAL PRICE INCREASES[1]	
	BLS Data	Manufacturers' Data
Model Year 1973-1974		
EPA Estimate	1.32-1.45	1.54-1.69
Industry Estimate	.72-1.74	.85-2.03
Model Year 1975-1976		
EPA Estimate	.93-1.02	.95-1.05
Industry Estimate	.51-2.31	.53-2.37
Model Year 1980		
EPA Estimate	.82	

---

[1] These price increases are that portion of the reported price increases which are attributable to addition or improvement of pollution control equipment.

Source: Putnam Ibid.

the deduction is smaller simply because the percentage of labor and capital devoted to pollution abatement was not rising as fast in the 1975-1978 period.

Public Interest Economics Foundation

The Public Interest Economics Foundation prepared a report for the Natural Resources Defense Council on the macroeconomic impacts of the Clean Air Act. 20/ The report reviews published reports on the macroeconomic impacts of the Clean Air Act, including the range of estimates obtained for effects on economic growth, inflation, unemployment, and labor productivity.

The report reviewed the composition of the principal sources of national pollution control costs data. These include the incremental cost estimates of EPA, the total pollution control outlays developed by BEA, the industrial capital cost estimates developed by the Bureau of Census, and estimated capital investment by McGraw-Hill. The report states that the BEA data is considered to be the most consistent and accurate source of historical data on capital and annual costs. The Bureau of Census estimate, because of its very extensive data, is the most precise; however, it is only available for the manufacturing sectors of the economy. The McGraw-Hill data, according to the authors, are not useful for macroeconomic assessments. The EPA estimates are the only data reflecting the incremental costs of pollution control.

20/ Wolcott, Robert M. and Adam Z. Rose. The Economic Effects of the Clean Air Act. A report prepared for the Natural Resources Defense Council by the Public Interest Economics Foundation. March 1982.

The report analyzed eight studies of the aggregate impact of pollution control on the U.S. economy to determine the scope and bias of each. A summary of the findings is presented in table 18. The studies differ somewhat in terms of time period and geographic location, regulation involved and indicators measured. All of them, however, indicate that the economic impacts are either negligible or minor.

The review and synthesis resulted in the following conclusions regarding the impact of the Clean Air Act on the economy:

- Output has remained essentially unchanged, with only a modest reduction of approximately 0.1 percent per year. When adjusted to take into account benefits not reflected in market transactions (such as the value of improved health), real welfare has increased;
- Unemployment was 0.1 to 0.2 percent lower per year than it would have been without clean air legislation;
- Prices (measured by the Consumer Price Index) increased very slightly, from 0.1 to 0.2 percent per year. Consideration of benefits not reflected in market transactions suggests that air pollution controls have had virtually no effect on inflation;
- Relaxing air quality requirements enough to reduce capital costs for air pollution control by 30 percent would change output, prices, and employment imperceptibly, by less than 0.1 percent for each indicator;
- Labor productivity, as conventionally measured, has been essentially unaffected, with a reduction of less than one percent per year reported by the most adverse studies. Recent work incorporating the Act's non-market benefits into conventional measures of output, suggests that the Act has increased labor productivity;

Table 18. Summary of Findings

Study	Area Period	Regulations Covered	Impacts (percentage change)[a] Output[b]	Employment	Inflation[c]	Study Bias[d]
Chase (1975)	U.S./ 1974-82	Clean Air Act, Clean Water Act/ Stationary Sources	-1.59 to +1.51[e]	-.42 to +.39	n.e.	High investment displacement assumption; high price mark-ups
DRI (1979)	U.S./ 1970-86	Clean Air Act, Clean Water Act/ Stationary Sources	-.89 to +.60[e]	+.17 to +.47	+.11 to +.50	No displacement from government spending
DRI (1981)	U.S./ 1970-87	Clean Air Act, Clean Water Act/ Stationary Sources	-.31 to +.24[e]	+.10 to +.41	+.12 to +.76	No displacement from government spending; full price mark-ups
Hollenbeck (1979)	U.S./ 1973	Clean Air Act/ Stationary Sources	-.12	-.07	+.02	Full price mark-ups; limited earnings increase
ETA (1980)	Minneapolis SMSA/1980s	1977 CAA Amendments/ Particulate Matter, SOx, HC	-.02 to +.01	-.04 to +.02	n.e.	Arbitrary investment displacement assumption; crude employment coefficient
JACA (1980)	Ohio River Valley/1980s	1977 CAA Amendments/ 5 Major Pollutants	-1.27 to +2.54	-0.25 to +3.71	n.e.	No investment displacement; full mark-up
Miernyk (1974)	West Va./ 1975	Clean Air Act + W. Va. Regs/				
		Particulate Matter	+1.34	n.e.	n.e.	Lack of price feedbacks
		Sulfur Oxides	+4.30	n.e.	n.e.	

Table 18. Summary of Findings Continued

Rose (1981)	San Diego SMSA 1982	1977 CAA Amendments/ 5 Major Pollutants	-.9 to +.4[f/]	-.9 to +.4[f/]	-.2 to +.3[f/]

---

n.e. Not estimated

a/ Where ranges are given (except Rose), ranges reflect year of most favorable and unfavorable impact

b/ Output measured as Total Gross Output except as indicated

c/ Inflation measured in terms of annual percentage change in CPI

d/ See also the discussion of the studies in text

e/ Based on the Index of Industrial Production

f/ Ranges reflect different assumption used in sensitivity analysis

Source: Wolcott, Robert M. and Adam Z. Rose. The Economic Effects of the Clean Air Act. A report prepared for the Natural Resources Defense Council by the Public Interest Economics Foundation. March 1982.

- The Clean Air Act's benefits substantially exceed compliance costs. The most comprehensive survey to date estimates benefits of $21.4 billion, and costs of $17.0 billion;
- Compliance expenditures by the private sector have remained stable in real terms since 1975 -- on average, less than 3 percent of gross private domestic investment. Total expenditures by business, consumers and government were 0.6 percent of GNP for the 1972-1979 period;
- Abatement costs could be reduced further by continued use of emission offsets and other market-based "controlled trading" mechanisms. 21/

In short, the study concludes that the evidence will not support charges that the Clean Air Act is imposing severe costs on the U.S. economy. Net benefits have resulted, and macroeconomic measures have remained essentially unchanged. According to the study, the Clean Air Act is, on balance, sound environmental policy and is consistent with sound economic policy. 22/

C. SITING

Clearly the issue of siting industrial faculities has changed from the conditions that existed during and immediately following World War II. The environmental laws enacted in the 1970s enlarged the considerations for siting nearly all industrial and community developments. They added

---

21/ Wolcott. Ibid., pp. i-ii.

22/ Wolcott. Ibid., p. ii.

environmental requirements to considerations of how to maximize market potentials, utilization of transportation, availability of labor, and other factors important to success.

Some critics have charged that these new laws and regulations injure the industrial economy of the Nation in that huge sums of money are required to meet environmental regulations and these "unnecessary" expenditures drive up inflation and stifle productivity. These costs of compliance are said to place domestic firms at a disadvantage in competing with foreign industry. Moreover, the complexity of reviews and permitting requirements are blocking construction or causing undue delays in constructing new facilities, according to these critics. One result, it is charged, is to encourage industries to move overseas where environmental constraints may be less onerous. This section reviews these issues.

Flight of Industry

The Conservation Foundation study entitled "Siting New Industry: An Environmental Perspective" addresses two major siting issues. 23/ One of the most common concerns is that environmental quality regulations are causing flight of industry to other countries. The Foundation found no credible evidence to support the allegation that environmental regulations have or are about to precipitate a significant movement of domestic industry to foreign countries. These conclusions, similar to those of the

---

23/ Duerksen, Christopher J. Siting New Industry: An Environmental Perspective. The Conservation Foundation. Washington, D.C. Oct. 1982.

Department of Commerce, 24/ the United Nations, 25/ and the Organization for Economic Cooperation and Development, suggest that locational factors, political stability, labor costs, and age of production facilities are factors that exert pressures equal to or exceeding pressures resulting from environmental requirements.

Another issue, that industry is moving to new locations within the United States because of weak environmental laws or lax enforcement, was found to be lacking in statistically significant support. Enactment of Federal environmental legislation in the 1970s quieted the old "environmental blackmail" debate. Nonetheless, the issue reappears periodically.

Howard Stafford, a professor at the University of Cincinnati, in another study for the National Science Foundation found that environmental regulation do not lead to shifts in location of industry within the United States. 26/ Environmental regulations were only of mid-level locational importance and were consistently overshadowed by labor availability, markets, and material access considerations. Other determining factors included transportation costs and availability, utilities, quality of life, business climate, labor costs, taxes, and site characteristics. The author of the report states that there is little to suggest that the general thrust of environmental protection should be altered because of concern for siting.

24/ The Effects of Pollution Abatement on International Trade IV. Department of Commerce. November 1976.

25/ Leontief, Wassily. et. al. The Future of the World Economy. A United Nations Study. Oxford University Press. New York. 1977.

26/ Environmental Rules Cause Few Shifts in Industrial Location, New Study finds. National Science Foundation News. NSF.PR 83-38.

Concerns about industrial flight of manufacturing industries to other countries was the focus of another Conservation Foundation--sponsored study. 27/ The study found:

1. Environmental regulations have not caused a significant exodus of U.S. industry;
2. A few industries appear to have been pushed abroad;
3. Most newly constructed plants owned by U.S. companies in rapidly industrializing countries overcomply with local enviromental and workplace standards. 28/

Delay of Construction

Another issue addressed by the Conservation Foundation was the allegation that industrial projects such as Hampton Roads, SOHIO Pactex, Colstrip, and the Alaskan Pipeline were blocked or delayed by environmental regulations. The Foundation found that environmental and land use regulations did delay projects; however, in many cases the major causes of delays did not stem from Federal regulations but from local, State, and regional requirements. The Foundation concluded that there is increasing evidence that the number and intensity of environmental conflicts in the United States are decreasing as the players in the siting game learn the ground rules.

The complexity of current industry is an important factor in delay. Even if all regulations were repealed, the Foundation reports, it would take four to five years to plan and construct a petrochemical facility. 29/

27/ Leonard H. Jeffrey. Siting New Industry: An International Perspective. The Conservation Foundation.

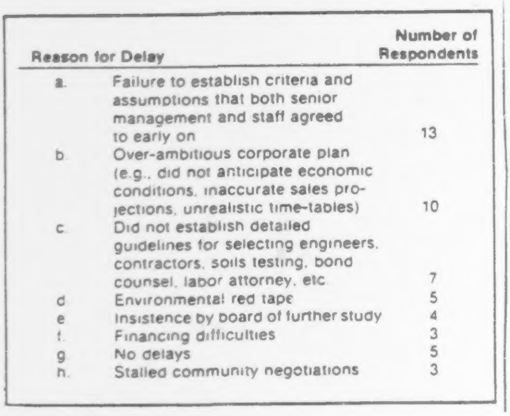
28/ Leonard, Ibid., p. 7-13.

29/ Duerksen, Ibid., p. 31.

The reader will recognize that conditions of 30-40 years ago do not exist today. Earlier plant location was predicated on raw materials, labor, and markets. A study completed in 1982 reminds us that many conditions have changed since 1960, including: race relations, attitudes of elected public officials antagonistic toward or against business, and the rise of vocal environmental and consumer movements that alter the decisionmaking picture. 30/ Another often overlooked condition is the compression of people as population grows and the accompanying pressure on resources to satisfy their needs. The intricate web of economic, social, and political forces places greater demands on industrial decision makers. The mix of factors that have caused delays are tabulated and presented in table 19.

30/ Donovan, Dennis J. Twelve Key Questions for Site Selection Decision-Makers. Industrial Development. July/August 1982.

TABLE 19. Reasons Given for Costly Project Delays in Survey of 50 Firms



Reason for Delay		Number of Respondents
a.	Failure to establish criteria and assumptions that both senior management and staff agreed to early on	13
b.	Over-ambitious corporate plan (e.g., did not anticipate economic conditions, inaccurate sales projections, unrealistic time-tables)	10
c.	Did not establish detailed guidelines for selecting engineers, contractors, soils testing, bond counsel, labor attorney, etc.	7
d.	Environmental red tape	5
e.	Insistence by board of further study	4
f.	Financing difficulties	3
g.	No delays	5
h.	Stalled community negotiations	3

Source: Donovan, Dennis J. Twelve Key Questions for Site Selection Decision-Makers. Industrial Development. July/August 1982.

BENEFIT-COST ANALYSIS IN ENVIRONMENTAL DECISIONMAKING

The term benefit-cost analysis has become increasingly commonplace in the discussion of regulation. Benefit-cost analysis is a formal procedure, based on specialized techniques and principles, for comparing benefits and costs of alternative policies. One might expect it to be characterized by precision and general acceptance, but instead the basic concepts of benefit-cost analysis are the center of many debates and much confusion, even among economists.

Environmental programs have been caught up in intense political and philosophical disputes over how the Government should make decisions. To some individuals the name of the game is benefit-cost analysis. In many cases, the clamor for benefit-cost solutions must remain rhetorical since it is extremely difficult to monetize benefits or account for costs accurately. 31/

This section reviews the evolution of benefit-cost analysis, the role of benefit-cost analysis in decision-making, and presents a critical review of estimating benefits for air and water pollution control. The requirements of Executive Order 12291 will be reviewed.

31/ The author prefers to use the term "benefit-cost analysis" rather than the cost-benefit analysis.

EVOLUTION OF BENEFIT-COST ANALYSES

Benefit-cost analysis, as a technique, has evolved since its first requirement by the Flood Control Act of 1936. Section 1 of the Act emphasized that the Federal Government shall participate in flood control "if the benefits to whomever they may accrue are in excess of the estimated costs and if lives and the social security of people are otherwise adversely affected." Despite this legal requirement, uniform guidelines were not published until 1950.

The Corps of Engineers, the Departments of Interior, Agriculture, and Commerce and the Federal Power Commission acting cooperatively in the Subcommittee on Benefits and Costs of the Federal Inter-Agency River Basin Committee released their report in May 1950. This report, commonly referred to as the "Green Book," became the voluntary guidelines for application in their respective activities in river basin development. The Green Book addressed and defined primary and secondary benefits, and tangible and intangible benefits. The report stressed that improvement of health or loss of life may be assigned values "on the basis of agreed upon estimates of acceptable expenditures."

Although the Green Book was revised and reissued in May 1958, the guidelines had no official standing in planning and assessing water resources development projects. It was not until the issuance of Senate Document

---

[32] Executive Office of the President. Annual Report of the Council of Economic Advisers in Economic Report of the President. Washington, D.C. U.S. Government Printing Office. 1982. p. 142.

No. 97 that benefit-cost analysis attained an official status. 33/ The Document stressed three major objectives of planning: development; preservation; and well-being of people. The latter objective is defined as follows:

> Well-being of all of the people shall be the overriding determinant in considering the best use of water and related land resources. Hardship and the basic needs of particular groups within the public shall be a concern, but care shall be taken to avoid resource use and development for the benefit of a few or the disadvantage of many. In particular, policy requirements and guides established by the Congress and aimed at assuring that the use of natural resources, including water resources, safeguard the interests of all of our people shall be observed. 34/

The Document specified that effects may be composited roughly into tangible and intangible categories; and in situations where no adequate means can be devised to evaluate directly the econmic effects, "the costs of achieving the results by the most likely alternative may be used as an approximation of value." 35/

Senate Document No. 97 was replaced by "Principles and Standards" published in 1973. 36/ In addressing the beneficial effects of life,

---

33/ U.S. Congress. Senate. Policies, Standards, and Procedures in the Formulation, Evaluation, and Review of Plans for Use in Development of Water and Related Land Resources. Senate Document No. 97. 87th Congress. 2d Session. Washington, D.C. U.S. Government Printing Office. May 29, 1962.

34/ Senate Document no. 97. Ibid., p. 2

35/ Ibid., p. 9.

36/ Water Resources Council. Establishment of Principles and Standards for Water and Related Land Resources. 38 FR 83. September 10, 1973.

health, safety, and reducing the concentration and exposure to water and air pollution, the Principle and Standards held that:

> In those situations where historical experience is sufficiently documented to provide confidence in projecting likely future hazards, an estimate of the number of persons affected may be provided. In most instances, however, a descriptive-qualitative interpretation and evaluation of the improvement and expected results will be applicable. Conversely, adverse effects are identified or described as increases in hazards to life, health and safety. 37/

Subsequent amendments or revisions to the Principles and Standards call for a display of the number of persons affected, but at no time during the fifty year evolution of benefit-cost analysis has a direct value been placed on life, health, or safety.

Attempts to assess benefits of environmental programs, outside the water resource planning area, have been extremely controversial. Many of the controversies center on the values placed on mortality, morbidity, aesthetics, vegetation, and materials. Many so-called benefit studies begin and end with a tabulation of pollution damage estimates. Other studies attempt to translate the damages into benefits.

BENEFIT-COST ANALYSIS AND DECISION-MAKING

It is generally agreed that the theory of benefit-cost analysis is well developed; however, there is no consensus on the utility of benefit-cost analysis in decisionmaking. Variations and uncertainties about estimates arise from four problem areas in the process: specification; measurement; valuations; and aggregations.

37/ Water Resources Council. Ibid.

Specification errors stem from the inability to define or account for all important variables and relationships. The lack of observations on variables such as property rights, technology changes, micro-climates, cultural expectations and so on can drastically change the outcome of benefit-cost analyses.

Measurement errors, generally, arise from errors resulting from monitoring locations, averaging and aggregation difficulties, errors in characterization of the population at risk, inability to separate effects of co-factors and other process difficulties.

Valuation errors appear because of the inability to assign acceptable values to certain physical, biological, aesthetic, and psychic effects.

Aggregation errors result from attempts to extrapolate local or regional estimates to national levels or from attempts to derive future values from past and current estimates.

Benefits by definition, are desirable effects; however, some criteria are required to define and measure desirability. Welfare economics has conventionally used efficiency and equity as criteria for judging economic conditions. Efficiency refers to the availability of goods and services and their value irrespective of whom they accrue to. Equity is concerned with the pattern of distribution of goods and services among individuals. Equity involves value judgments about the entitlement of individuals.

Economic analysis, for this reason, focuses on the efficiency criterion using the argument that efficiency is relatively value-free or objective. But assigning values or prices to goods and services, or to mortality and morbidity, may be far from a value-free or objective analysis.

Public policy, as often expressed, is not concerned solely with efficient resource allocation; instead, it is also concerned with the equity or redistributional aspects of these policies. Thus, in addition to providing information on benefits and costs, economists can serve policymakers by providing additional information on who benefits from environmental improvements and who is hurt by environmental degradation. 38/

The calls for benefit-cost analysis are increasing, suggesting that this form of analysis is increasingly viewed as a useful a decisionmaking tool. Benefit-cost analysis can be valuable in organizing and expressing certain types of information on a range of alternatives. Nevertheless, many individuals distrust efforts of analysts to perform benefit-cost analysis. They consider the extension of economic measurement to human life, health, ecology, and aesthetics and converting these to monetary values as crass and impersonal.

The success of benefit-cost analysis depends not only on the availability of data but on the objectivity of the analyst. Dr. Baruch Fischoff testified before a congressional committee on how an analyst can manipulate any desired conclusion:

> My colleague *** reports being in the back wards of a District of Columbia area consulting firm, and seeing an analyst hunched over a terminal massaging a computerized analysis. Said he, "the analysis didn't come out the way my client wanted it. However, there's quite a bit of wiggle room or ambiguity in almost all of the cost, benefit, and probability assessments. I'm just going to alter each a little bit until I get the right conclusion. No one will

---

38/ Freeman, A. Myrick III. The Benefit of Environmental Improvement. Theory and Practice. Published for Resources for the Future by the Johns Hopkins Press. Baltimore. 1979. p. 262.

> notice and my client will be happy with this justification for what he was going to do anyway. 39/

In order not to mislead the decision-maker, all critical assumptions and uncertainities must be identified and all weaknesses must be made known. The absence of these conditions or a lack of information can result in analyses that may be more misleading than useful.

The term benefit-cost analysis has an intrinsic appeal to most people because it suggests sound common sense decisionmaking. But from another perspective, benefit-cost analysis suggests indecision or at least a lack of a specific goal or objective.

Given the difficulties associated with benefit-cost analysis, the decision-makers should be ever conscious that benefit-cost analysis is an economic analytical tool. Benefit-cost analysis does not dictate choices or abrogate the authority or responsibility of the decision-maker.

DAMAGE ESTIMATES

Benefits of controlling pollution arise from gains resulting from improvements in the quality of the environment. Such gains can be either a reduction of damages caused by pollution or an increase in options made available because of an improved environment, e.g, recreational opportunities. Theoretically, prevention of damages is the benefit resulting

---

39/ U.S. Congress. House. Committee on Interstate and Foreign Commerce. Subcommittee on Oversight and Investigations. Cost-Benefit Analysis: Wonder Tool or Mirage? Committee Print. 96th Congress, 2d Session. Washington, D.C. U.S. Government Printing Office. December 1980. p. 5.

from removal of pollutants from the environment; thus, damage assessments emerge as rough estimates of potential benefits.

The most recent comprehensive study of damage estimates was published in 1978. 40/ This report, hereafter refered to as the Hershaft report, draws heavily on work of Heintz 41/ and Waddell 42/. The Hershaft report stresses that many types of damages are not amenable to quantification in monetary terms, because of their nature and the state-of-the-art of measurement methods. Such difficult-to-measure damages account for a substantial portion of the damages caused by pollution and include loss of well-being, pain, anxiety, displeasure, impaired health and so on.

Estimates of air pollution damages by Heintz are summarized in four categories (table 20). Heintz estimates that damages from air pollution in 1973 ranged from $9.5 to $35.4 billion, with a best estimate of $20.2 billion. These estimates do not include a number of categories of potential damages for which estimates are not available. The most important of these may be the threat to unique ecosystems and species. The absence of such assessments could significantly alter decisionmaking and have a profound

---

40/ Hershaft, A. (ed) A.M. Freeman III, T.D. Crocker, and J.B. Stevens. Critical Review of Estimating Benefits of Air and Water Pollution Control. EPA-600/5-78-014. Prepared for the U.S. Environmental Protection Agency. Office of Health and Ecological Effects. Office of Research and Development. Washington, D.C. 1978.

41/ Heintz, H.T., A. Hershaft, and G.C. Horak. National Damages of Air and Water Pollution. A report prepared for the U.S. Environmental Protection Agency. (Contract No. 68-01-282). September 1976.

42/ Waddell, Thomas E. The Economic Damages of Air Pollution. EPA-600/5-74-012. U.S. Environmental Protection Agency. Washington, D.C. May 1974.

TABLE 20. ESTIMATED DAMAGES OF AIR POLLUTION FOR 1973
(billions of dollars)

Damage Category	Best Estimate	Range Low	 High
Health	$ 5.7	$ 2.0	$ 9.4
Aesthetics	9.7	5.7	13.7
Vegetation	2.9	1.0	9.6
Materials	1.9	0.8	2.7
TOTAL	20.2	9.5	35.4

Source: Heintz, H.T., Jr., A. Hershaft, and G.C. Horak. National Damages of Air and Water Pollution Control. U.S. Environmental Protection Agency. (Contract No. 68-01-2821). September 1976.

effect on future economic activities. The authors, Heintz, et. al., expressed serious reservations about the accuracy and reliability of the information. Their evaluation of the data is presented in table 21.

TABLE 21. AVAILABILITY AND RELIABILITY OF INFORMATION ON AIR POLLUTION

Damages							
Damage Category	NOx	Oxidants	SOx	CO	HC	Particulates	Other
Human Health	SF	SF	IG	SF	SF	IG	IF
Aesthetics	U	SF	IG	U	U	IF	U
Vegetation	IF	IG	IF	SF	SF	SF	SF
Materials	SF	IF	IG	SP	SP	SG	U

Availability	Reliability
A - Ample	E - Excellent
I - Insufficient	G - Good
S - Scarce	F - Fair
U - Unavailable	P - Poor

NOx - Nitrogen Oxides

SOx - Sulfur Dioxide

CO - Carbon Monoxide

Hc - Hydrocarbon

Source: Heintz, H.T., Jr., A. Hershaft, and G.C. Horak. National Damages of Air and Water Pollution Control. U.S. Environmental Protection Agency. (Contract No. 68-01-2821). September 1976.

The most available data on effects concern the impacts of sulfur oxides, oxidants, and particulates on human health and on vegetation.

A key consideration in estimating damages to health by air pollution is the valuation of life. For example, if valuations are based on a specific stream of earnings then those who receive no compensation for labor fail to be counted. This includes housewives, children, retirees, volunteers, and others. Hershaft noted that there is no logical connection between value of future earnings and willingness to pay. 43/

Heintz's estimate of water pollution damages range from $4.5 billion to $18.7 billion, with a best estimate of $10.1 billion. These estimates for 1973 show the damages to be the greatest in the recreational, aesthetic, and ecological categories (table 22). The key problem in quantifying health damages is the problem of how best to deal with the uncertain, long-term relationships such as the presence and effects of carcinogens. 44/ Again the valuation of health and human life becomes crucial in the assessments.

43/ Hershaft. Ibid., p. I-23-I-24.

44/ Hershaft. Ibid., p. I-32.

TABLE 22. ESTIMATED NATIONAL DAMAGES OF WATER POLLUTION FOR 1973
(billions of dollars)

Damage	Best Estimate	Range Low	Range High
Outdoor Recreation	$ 6.3	$ 2.5	$ 12.6
Aesthetics and Ecological	1.5	0.6	2.8
Health	0.6	0.3	1.0
Production	1.1	1.1	2.3
TOTAL	10.1	4.5	18.7

Source: Heintz, H.T., Jr., A. Hershaft, and G.C. Horak. National Damages of Air and Water Pollution Control. U.S. Environmental Protection Agency. (Contract No. 68-01-2821). September 1976.

Heintz reviewed a broad spectrum of studies to arrive at his damage estimates and in doing so he developed his assessment on the availability and reliability of data (table 23). It will noted that data on health damage relationships are largely lacking.

TABLE 23. AVAILABILITY AND RELIABILITY OF INFORMATION FOR WATER POLLUTION DAMAGES

Pollutant	Outdoor Recreation	Aesthetics and Ecological	Health	Production Loss
Acidity	SF	U	U	SP
BOD	IF	SP	U	IF
Coliform Bacteria	SF	U	SP	SP
Floating	IF	U	U	SP
Hardness	U	U	U	IP
Nutients	SP	U	U	SP
Odor	U	U	U	U
Oil	SP	SP	U	SP
Pesticides	U	U	U	U
Sediment	IF	IF	U	IF
Temperature	IF	SP	U	SP
TDS and Salinity	U	U	U	IF
TSS and Turbidity	SF	U	U	SP
Toxic Metals	SP	U	U	SP
General Pollution	AF	SP	SP	IF

Availability

A - Ample

I - Insufficient

S - Scarce

U - Unavailable

Reliability

E - Excellent

G - Good

F - Fair

P - Poor

Source: Heintz, H.T., Jr., A. Hershaft, and G. C. Horak. National Damages of Air and Water Pollution Control. U.S. Environmental Protection Agency. (Contract No. 68-01-2821). September 1976.

BENEFIT ASSESSMENTS

Certainly benefit assessments are most important in establishing the relationship of benefits and costs of regulation. It was for this reason that the Council on Environmental Quality sponsored a study of the benefits of air and water pollution control. 45/ In contrast to the damage estimates compiled by Heintz, et. al., Professor A. Myrick Freeman III, Bowdoin College, compiled estimates of air and water pollution-control benefits. Freeman's study consisted of a review and synthesis of benefits to accomplish four objectives: (1) review the theoretical framework; (2) explain the differences in earlier studies; (3) recalculate the benefits to a common set of assumptions; and (4) present a "best judgment" estimate of the current benefits of air and water pollution control.

Freeman's "most reasonable point estimate" of the benefits of air pollution was $21.4 billion in 1978, based on 1978 dollars. He cautioned that the $21.4 billion point estimate should not be used without noting the lower and upper bounds ($4.6-$51.2 billion); to do so would convey a false sense of accuracy or certainty. Ranges for each benefit category are presented in table 24. In Freeman's judgment, there is a 90 percent certainty that the true value lies within the given range. It is interesting that health benefits identified by Freeman surpass all other categories. This is a sharp departure from the Heintz damage study where aesthetics suffered the most damage in the earlier estimate. The reader

---

45 / Freeman, A. Myrick III. The Benefits of Air and Water Pollution Control: A Review and Synthesis of Recent Estimates. A report prepared for the Council on Environmental Quality. Washington, D.C. December 1979.

TABLE 24. AIR POLLUTION CONTROL BENEFITS ENJOYED IN 1978
(In billions of 1978 dollars)

	Realized Benefits	
Category	Range	Most Reasonable Point Estimate
Health	$2.8 -- 27.8	$13.9
Stationary Source		
Mortality	.29 - 11.5	2.9
Morbidity	3.1 -- 39.3	16.8
Total	0 -- .4	.2
Mobile Source		
Total Health	3.1 -- 39.7	17.0
Soiling and Cleaning	.5 -- 5.0	2.0
Vegetation		
Stationary Source	0	0
Mobile Source	.2 -- 2.4	.7
Total Vegetation	.2 -- 2.4	.7
Materials		
Stationary Source	.4 -- 1.1	.7
Mobile Source	.1 -- .3	.2
Total	.5 -- 1.4	.9
Property Values		
Stationary Source	5.9 -- 6.9	2.3
Mobile Source	.2 -- 2.0	.4
Total	1.1 -- 8.9	2.7
GRAND TOTAL	$4.6 -- 51.2	$21.4

Source: Freeman, A. Myrick III. The Benefits of Air and Water Pollution Control: A Review and Synthesis of Recent Estimates. A Report Prepared for the Council on Environmental Quality. December 1979.

will note considerable differences in the categories of damage and benefits. Freeman's assessment of water pollution control benefits deviates from the format he established for his assessment of air pollution control benefits. The benefits for air pollution control are expressed as values for 1978, in 1978 dollars, but his assessment of water quality benefits reflect those that will accrue in 1985, expressed in 1978 dollars. Benefits range from $6.6 billion to $24.8 billion, with a most likely point estimate of $12.3 billion (table 25).

Freeman stresses that water pollution control benefits are much more difficult to estimate than those arising from air pollution control. There are more indicators of water quality, and estimating the impacts of non-point sources of water pollution is difficult, if not impossible. Thus, the estimates presented by Freeman include only the conventional point source control benefits.

TABLE 25. BENEFITS IN 1985 FROM REMOVAL OF CONVENTIONAL WATER POLLUTANTS (In billions of 1978 dollars)

Category	Range	Most Likely Point Estimate
Recreation	$ 4.1 -- 14.1	$ 6.7
Non-user Benefits--		
aesthetics, ecology, & property values	1.0 -- 5.0	2.0
Diversion Uses		
Drinking water-		
Health	0.0 -- 2.0	1.0
Municipal Treatment	0.6 -- 1.2	0.9
Households	0.1 -- 0.5	0.3
Industrial Supplies	0.4 -- 0.8	0.6
Commercial Fisheries	0.4 -- 1.2	0.8
Total	$ 0.4 -- 24.8	$ 12.3

Source: Freeman, A. Myrick III. The Benefits of Air and Water Pollution Control: A Review and Synthesis of Recent Estimates. A Report Prepared for the Council on Environmental Quality. December 1979.

From his study, Freeman concludes that, in spite of recent advances, estimating certain environmental benefits is still in need of much additional refinement. He adds that the state-of-the-art analyses of environmental benefits that have been undertaken strongly suggest that environmental protection is good economics." 46/

COSTS

Here the term "costs" is used only to refer to expenditures for controlling or abating pollution. It is this sense of cost which forms the second part of benefit-cost analysis.

The comparison of benefits to costs must have specific reference points, i.e., the comparison must reflect the conditions of benefits and costs under specific variables of time, place, activity and so on.

Cost estimates reviewed earlier in this report were developed for specific purposes and reflect considerable variation. Some of the cost data are incomplete and in many cases inadequate for benefit-cost comparisons. In some cases industry sponsored studies of environmental expenditures allege excessive and unnecessary costs. For example, one Business Roundtable study stated:

> Virtually every problem cited in the case studies is reflected as an unnecessary cost ultimately borne by consumers and the economy at large. Typically, the most serious excess costs are the opportunity costs reflecting lost production resulting from delays, and inefficiency production resulting from constraints of scale, operation or location. 47/

46/ Freeman. Ibid., p. xii.

47/ Effects of the Clean Air Act on Industrial Planning and Development: Analysis of Case Studies. Vol. 1. Environmental Research and Technology Inc. July 1981, p. S.4.

However, these assertions have not been independently verified.

Efforts to assess benefits and costs of pollution control have ranged from the level of how the statutes work to how individual regulations impact specific businesses. As discussed earlier, existing aggregated cost data are not usable in evaluating the statutes or major programs, and EPA's and CEQ's ending their data series would seem to make future analyses even more difficult.

Attention has now shifted more to assessing the benefits and costs on microeconomic scales, such as required by Executive Order 12291, described in the next section. At this level of analysis, cost data are regularly generated in preparing certain kinds of regulations--for example, New Source Performance Standards--the Clean Air Act specifies that these shall be economically achievable. Nevertheless, the Act does not permit analysts to relate directly the resulting environmental benefits to the costs; rather, the requirements are for nationally uniform technological standards regardless of resulting local environmental conditions. Moreover, as national standards, local environmental conditions cannot considered in evaluation the benefits of control at a specific source.

This statutory separation of costs from benefits, and from local environmental conditions, thus constrains the generalized use of benefit-cost analysis in specific situations. In effect, benefit-cost analysis remains as a guide to policymakers who are setting standards, but it does not and can not replace this judgment.

EXECUTIVE ORDER 12291

One month after assuming office, President Reagan issued Executive Order 12291. 48/ A major thrust of this order stipulates that a regulation may be promulgated only if the potential benefits to society outweight the potential costs of the proposed action. To make this determination, Federal agencies must perform a regulatory impact analysis (RIA) on all major regulations and submit these to the Office of Management and Budget (OMB).

A major regulation is one that is likely to result in:

1. An annual effect on the economy of $100 million or more;
2. A major increase in costs or prices for consumers, industries, Federal, State or local government agencies or geographic regions;
3. Significant adverse effect on competition, employment, investment, productivity, innovation, or the ability of U.S.-based enterprises to compete with foreign-based enterprises in domestic or foreign markets. 49/

According to the White House, the Executive order will produce better quality regulations and reduce the excess burden of regulation on the American people. The order:

. Instructs the agencies on what is expected of them with respect to their regulatory work and provides reassurance to the American people of the Government's ability to control its regulatory activities.

. Charges the Office of Management and Budget with administering the new order, subject to the overall direction of the Presidential Task Force on Regulatory Relief.

48/ Executive Office of the President. Federal Regulations. Executive Order 12291. February 17, 1981.

49/ E.O. 12291. Ibid.

- Emphasizes that regulatory decisions should be based on adequate information; actions should not be undertaken unless the potential benefits to society outweigh the potential costs; and regulatory priorities should be set on the basis of net benefits to society.

- Directs agencies to determine the most cost-effective approach for meeting any given regulatory objective, and requires that factors such as the economic condition of industry, the national economy, and prospective regulations be taken into account.

- Requires each agency to perform certain tasks as part of the development of an imporant regulation. A Regulatory Impact Analysis is required to evaluate potential benefits and costs in light of the regulatory objectives. A determination must be made that any proposed rule is consistent with applicable legal authority and Presidential policy and that it reflects careful evaluation of the comments of all persons affected by or interested in the regulation. The Task Force is to oversee this process; the Office of Management and Budget is to make substantive comments on regulatory analyses, help determine which new and existing regulations should be so analyzed, and oversee the publication of semiannual regulatory agenda. 50/

OMB had reviewed 2,715 proposed regulations through December 31, 1981, and had approved 2,546 of them as consistent with the Executive order. Agencies of the Federal Government had issued 40 major regulations; nineteen were supported by RIAs, while twenty-one were waived for reasons such as emergency conditions. 51/

50/ The White House. Office of the Press Secretary. President Reagan's Initiative to Reduce Regulatory Burdens. Fact Sheet. February 8, 1981.

51/ Executive Office of the President. Annual Report of the Council of Economic Advisers in Economic Report of the President. Washington, D.C. U.S. Government Printing Office. 1982. p. 142.

NEW ECONOMIC TECHNIQUES FOR POLLUTION CONTROL

In the decade since Earth Day in 1970, Congress has enacted many environmental laws. These laws and the regulations designed to carry them out often tell firms how much they can or can not discharge smoke--stack-by-smoke stack and pipe-by-pipe. More often than not, industry criticizes these regulations as imposing excessive costs and being unwarranted intrustion on engineering decisions. In response, many have looked to various economic techniques to foster economic efficiency and reduction of costs. These techniques include: the bubble approach for single firms; emissions trading that encompasses emissions banking, bubbles for groups of sources, netting, and offsets; and emission charges.

EARLY BUBBLE PROPOSALS

The bubble policy is an air pollution management strategy by which emissions from a group of sources are regulated together. It is based on the conviction that EPA and the States should be primarily concerned with a plant's overall impact on air quality rather than point-emission limitations. This policy gives plant managers the flexibility to treat total emissions as though they were emerging from an imaginary enclosure, or bubble, placed over all the relevant emission points. (Although conceptually the bubble could apply to both air and water programs, virtually all attention has concerned the former; as written, the Clean Water Act appears to prohibit any use of the bubble approach.)

The bubble policy is one of several EPA initiatives to incorporate market-like incentives in environmental decisionmaking. The first attempt to initiate a bubble policy was the promulgation of rules by EPA in 1975 to implement the new source performance standards (NSPS) in Section 111 of the Clean Air Act. EPA had proposed to define a stationary source as a combination of facilities, a definition that gave rise to the possibility of pollution reductions elsewhere in a plant so that an existing source could avoid NSPS when a new piece of equipment was added to the plant. A Federal court, however, invalidated these regulations (ASARCO, Inc. v. Environmental Protection Agency. 578 F. 2d 319. DC Cir. 1978). As a result, EPA was precluded from applying the bubble policy to new sources of pollution, i.e., facilities that are totally new or reconstructured.

EPA's new bubble policy, initiated in December 1979 (44 FR 71780), was designed to produce a coherent, easy-to-use system to achieve pollution reductions in a less costly manner. The policy did not relieve industry from the fundamental requirements of the Clean Air Act, but it did allow flexibility in selecting cost-reducing abatement requirements. It allowed pollution reduction tradeoffs between neighboring plants. This flexibility was hailed as one of the most successful efforts of EPA to allow industry to find the solutions to environmental degradation.

The bubble policy may be used by an existing source now in compliance with current emission reduction requirements and by sources on an EPA approved compliance schedule. The use of the bubble must be in concert with the State Implementation Plan (SIP) and must demonstrate:

a) that pollutant emissions reductions from the bubble or alternative plan will be greater than those authorized or specified in the original SIP;

b) that all emissions must be quantified directly or indirectly;

c) that pollution reductions are comparable, i.e., no trade-offs between categories--for example SO2 for particulates.

EPA contended that when properly applied the bubble policy "should promote greater economic efficiency and increased motivation by providing plant managers with an economic incentive to develop new control strategies". 52/

Broading the Economic Techniques

However, EPA has replaced the December 1979 bubble policy with a new policy stressing emissions trading, banking and use of emission reduction credits. 53/ This new policy established by EPA expands the opportunities for States and industry to use "less costly" control approaches. It includes bubbles, netting, and offsets, and banking (storage) of emission reduction credits (ERCs) for future use. These alternatives, according to EPA, do not alter existing air quality requirements; they simply give States and industries more flexibility. The new policy provides criteria for "generic" SIP rules under which States can approve bubbles or other trades without a Federal case-by-case SIP review.

Emissions trading involves the creation of surplus reductions of certain emission sources and use of these reductions to meet requirements

---

52/ Air Pollution Control: Recommendations for Alternative Emission Reduction Options Within State Implementation Plans. 44 FR 71780.

53/ Emission Trading Policy Statement; General Principles for Creation, Banking, and Use of Emission Reduction Credits. 47 FR 15076. April 7, 1982.

applicable to other emission sources. The new policy broadens opportunities for the bubbles use:

- Authorizes generic trading rules for all criteria pollutants;
- Extending use of the bubble to areas which lack approved demonstrations of attainment of the national ambient air quality standards;
- Expanding opportunities for use of bubbles as an alternative means of meeting reasonably available control technology (RACT) requirements;
- Reducing unnecessary requirements for detailed air quality modeling of the ambient impact of each trade;
- Reducing unnecessary constraints on trade involving open dust sources of particulate emissions;
- Allowing VOC [volatic organic compounds] and CO [carbon monoxide] sources more time to implement bubbles under administrative compliance schedules, consistent with reasonable further progress and statutory deadlines for attaining ambient standards;
- Allowing sources to use the bubble to come into compliance, instead of having to be on a compliance schedule with original SIP limits to be eligible to bubble; and
- Allowing broader use of emission reductions from shutdowns. 54/

Netting, another change in the April 1982 promulgation, removes the burden of new source review requirements for expanding or modernizing plants in PSD or non-attainment areas as long as any increase in plant-wide emissions is insignificant. By "netting out," the new facility may be exempt from

---

54/ 47 FR 15076-77.

requirements for preconstruction permits, monitoring and modeling, installation of Best Available Control Technology (BACT) or Lowest Achievable Emission Rate (LAER) control technology, offsets, and applicable bans on new construction.

Emission offsets were designed to permit industrial growth in nonattainment areas. New major stationary sources and modifications may be required to secure sufficient surplus emission reductions to more than "offset" their increased emissions.

Emission reduction banking was established to allow firms to store qualified emission reductions for later use in bubble, netting, or offset transactions. The banked emission reduction credits can be sold to firms seeking alternative ways to meet regulatory requirements more quickly.

The magic words--banking, bubbles, netting, and offsets--were the corner stones of EPA policy for regulatory reform. EPA held that:

> If implemented by states it can allow industry to use the bubble and other trading aproaches in additional circumstances and geographic areas. The policy will also reduce adversary tensions, allow states to benefit from industrial knowledge, and encourage quicker compliance, while reducing unnecessary federal review. It represents important regulatory reform, for states as well as industry, by encouraging greater flexibility in meeting air quality goals. 55/

EPA estimated that increased trading under this policy would save over $1 billion from the bubbles by the end of 1982. 56/ With estimated savings

---

55/ 47 FR 15076.

56/ Fabian, Cynthia L. EPA's New Bubble: Not Everyone Delighted. Chemical Engineering. July 29, 1982. pp. 24-26.

of this magnitude, it is no surprise that many industry spokesman gave support to the policy. Some air pollution control officials were displeased with the proposal, however. Beverly Fowler, director of the Texas Air Control Board's Control Strategy Division, objected because she felt that it was inappropriate for the State to act as a broker of "pollution rights" and furthermore companies do not have the right to pollute at certain levels. 57/ The Connecticut Department of Environmental Protection objected to the new policy's generosity in crediting sources for emission reduction and to the vagueness in the definition of what is tradable.

EPA's revised policy has not been supported by some business groups. Harvey Alter, Director of Environment and Land Resources at the U.S. Chamber of Commerce, stated the policy was basically unsound and only leads to more paperwork. 58/ Similarly some environmental groups were unhappy with EPA's proposal. The Natural Resource Defense Council, Inc. (NRDC) filed suit. NRDC held that the bubble concept violated the non-attainment goals of the Clean Air Act. The U.S. District Court of Appeals for the District of Columbia ruled that EPA had acted illegally in adopting a plantwide definition of source in nonattainment areas and thus, allowing industry to bubble in these areas. The court stated that Congress intended the Clean Air Act "to promote the cleanup of nonattainment areas" and

---

57/ Ibid., p. 25.

58/ A Court Pricks EPA's Bubble. Chemical Week. August 25, 1982. pp. 17-18.

therefore EPA's "employment of the bubble concept to shrink to relatively small size mandatory new source review in nonattainment areas, is impermissable." 59/

The Supreme Court has agreed to review the issue. 60/

Emission Charges

The arguments for the use of economic incentives today are not significantly different from those voiced a decade or so ago.* Simply stated the argument suggests that pollution is primarily an economic problem and little will be accomplished until it is understood and treated in economic terms. The most commonly suggested solution is the imposition of a charge or tax to encourage the reduction of a specific pollutant. Another solution is to establish funds.

Acid Rain Taxes

Illustrative of the calls for the use of pollution taxes are legislative proposals such as: S. 2001, the National Acid Deposition Act of 1983; and H.R. 4483. Each of these proposals would impose some form of tax in order reduce pollutants as well as to establish a fund.

59/ NRDC v. Gorsuch. 17 ERC 1825 (D.C. Cir. August 17, 1982).

60/ Chevron U.S.A., Inc. v. Natural Resources Defense Council, Inc. No. 82-1005, American Iron & Steel Institute v. Natural Resource Defense Council, Inc. No. 82-1247, and Ruckelshaus v. Natural Resources Defense Council, Inc., No. 82-1591, 51 U.S.L.W. 3857, 5/31/83.

*For a review of earlier arguments see: U.S. Congress. Senate. Committee on Environment and Public Works. Pollution Taxes, Effluent Charges, and Other Alternatives for Pollution Control. Committee Print. Serial 95-5. Washington, D.C., U.S. Government Printing Office. May 1977.

S. 2001 would establish a tax on (1) sulfur dioxide emissions from major stationary sources; (2) nitrogen oxide emissions from major stationary sources and (3) nitrogen oxide emissions from motor vehicles, aircraft, and heavy construction equipment. The Secretary of the Treasury, after consultation with the Administrator of EPA, would establish the rates of tax to be imposed. The Treasury would be required to establish an Acid Deposition Reduction Trust Fund. Five percent of the funds would be used to assist projects that demonstrate contol strategies that will substantially improve air quality. Two percent of the funds are ear-marked for development and demonstration of emission control technologies or to conduct research. The fund would also pay up to 70 percent of the capital costs necessary to implement control strategies identified on a priority list. The fund is limited to $40 billion to be collected between January 1, 1985 and December 31, 1994.

H.R. 3400, entitled the National Acid Control Deposition Control Act of 1983, would establish a trust fund under the direction of the Secretary of Treasury. The fund would derive contributions through the collection of one mill for each kilowatt hour of elecricity generated in the contiguous 48 States and on all electricity imported into the United States. Out of the fund, the Administrator of EPA would pay for 90 percent of the construction and installation of the technological system of continuous emission reduction necessary for each plant to comply with emission limitation.

H.R. 4483, the Acid Deposition Control Act of 1983, would provide an incentive for coal-burning electric-utilities and other coal users to reduce sulfur emissions in a way that they determine would cost them and their customers the least. The bill would impose a tax of 50 cents per pound of sulfur content of coal. It would apply to sulfur content in excess of the level that would pose environmental problem. Utilities that will install equipment to control sulfur dioxide emissions will be reimbursed for 90 percent of their costs.

Each of the above proposals would establish a fund which in part will be used to finance the installation of pollution control equipment. Thus, as explained below, the Acid Rain Fund differs somewhat from the Superfund and other fund generating proposals.

Superfund

Superfund was established to provide the means to clean up toxic waste dumps that have been discovered and that will be discovered and to provide compensation for damages and economic losses from spills, releases, and discharges. The Superfund tax is imposed on designated feedstocks used in producing chemicals.

The Administration of the Superfund differs from the proposed Acid Deposition Fund in that under the Superfund, EPA looks to the responsible parties to clean up the problem. If, for some reason, the responsible party cannot be determined or if the party does not respond, EPA offers the State the opportunity to take a lead role. If the State declines, the site becomes a Federal-lead project under the leadership of the Corps of Engineers.

Superfund establishes specific liability for firm and/or individuals for removal or remedial action incurred by the U.S. Government or the State and for damages accruing because of a release. In contrast, the Acid Deposition Act compensates the polluter by paying from 70 to 90 percent of the cost of equipment required to control pollution.

H.R. 3400, entitled the National Acid Control Deposition Control Act of 1983, would establish a trust fund under the Direction of the Secretary of Treasury. The fund would receive money from a one mill per each kilowatt hour fee on electricity (except nuclear) generated in the contigious 48 States and on all electricity imported into the United States. The fund would pay for 90 percent of the construction and installation of technological systems of continous emission reduction necessary for designated plant to comply with emission limitation.

The Congressional Office of Technology Assessment (OTA) undertook a study of the management of hazardous wastes in which they identified five policy options to improve protection nationwide. 61/ Given that Superfund expires in 1985, attention was given to various other options for handling hazardous wastes. OTA examined five policy options including:

1. Continue with the current program;
2. Extend Federal controls to more hazardous waste, and establish national regulatory standards based on specific technical criteria; also, restrict disposal of high-hazard waste on land, and improve procedures for permitting facilities and deregulating waste;

61/ U.S. Congress. Office of Technology Assessment. Technologies and Management Strategies for Hazardous Waste Control. March 1983.

3. Establish Federal fees on waste generators as an economic incentive to reduce the generation of waste and discourage land disposal; impose higher fees on generators of high-hazard waste that are land disposed; provide assistance for capital investments and research and development (R&D) for waste reduction and waste treatment;

4. Study the costs and advantages of classifying wastes and waste management facilities by degree-of-hazard to match hazards and risks with levels of regulatory control;

5. Examine the need for greater integration of Federal environmental programs to remove gaps, overlaps, and inconsistencies in the regulation of hazardous waste, and to make better use of technical data and personnel. [62]

Policy option 3 above is of particular interest in that it is based on fees to be imposed on waste generators to provide the "economic" incentive to reduce wastes. OTA's assessment of the advantages of the fee system include the following:

- o More waste reduction and treatment;
- o Costs for improved protection more equitably distributed;
- o Public concerns over siting alleviated. [63]

Key disadvantages of the economic incentive route according to OTA include these:

- o Near-term costs to industry increased;
- o Uncertain effects on firms, communities, and international competitiveness;
- o Illegal dumping may increase.

---

[62] OTA. Ibid., pp. 3-4.

[63] OTA. Ibid., p. 38.

The reader will note the inconsistencies between the list of advantages and disadvantages. For example, the advantages "more waste reduction and treatment" and "Public concern over siting alleviated" appear to be destroyed by the simple disadvantage "Illegal dumping may increase."

The majority of economists argues strongly for the use of fees or taxes as an incentive to reduce polluting; but fees alone will not specify the degree of control desired or needed. The equitable application of fees is premised on an accurate monitoring-enforcement system. Furthermore, income transfer problems arise from fees, and this alone open a pandora's box of issues and allegations.

The Organization for Economic Cooperation and Development (OECD) assessment of pollution charges led to the conclusion that "the exclusive use of charges for controlling toxic chemicals substances would not appear to be desirable." 64/

OECD adds, "toxic substances are mainly controlled by direct methods." 65/

The most succinct appraisal of economic incentives is presented below:

> Economic incentives are no panacea. They require more careful monitoring of pollutant emissions and more routine contacts between polluters and regulatory agencies to verify emissions, collect effluent fees, or transfer licenses. Economic incentives would not even eliminate litigation, since agencies would still have to take polluters who did not comply

---

63/ OTA. Ibid., p. 38.

64/ Pollution Charges in Practice. Organization for Economic Cooperation and Development. Paris. 1980. p. 113.

65/ OECD. Ibid., p. 114

> to court. However, the advantage would be in having a system that is easily understood, can be uniformly enforced, and contains detailed incentives to bring about a "correct" level of pollution. 66/

But what is the "correct" level?

66/ Lave, Lester B. and Gilbert S. Omenn. Clearing the Air. Reforming the Clean Air Act. The Brookings Institution. Washington, D.C. 1981. p 29.

CHANGING ROLE OF ECONOMICS

The environment is such an intense contemporary issue that it is difficult to appreciate that is not solely an issue of this age. The physical environment of urban communities today, in many respects, is greatly improved over those of previous centuries. Rutted roads and steaming miseries of unrefrigerated summers have been replaced with paved boulevards and automobile freeways, and air conditioned homes and offices. But technolgy and affluence are two edged swords; just as technology has enhanced mobility of the population, it subjects the same population to new forms of ubiquitous pollution.

Current debates arguably underplay the close relationship between the economy, resource use, and the environment. This relationship stems from the size of the economy, the prodigious amounts of resources used or consumed, and the large and increasing potential for environmental degradation. This potential for environmental degradation becomes obvious when one looks at the various growth patterns in the economy. Energy consumption, vehicle miles travelled, and pesticide production data could be used as surrogate measures of pollution potentials.

Energy consumption has increased exponentially and this suggests that, unless controlled, emissions also increase exponentially. Although a reversal in the growth trend has occurred in 1980 and continued in 1981 and 1982, the total energy consumed in 1982 is still two and a half times that of 1940 (table 26). Another surrogate estimate of the growth of potential pollution can be derived from vehicle miles traveled. In 1940, motor vehicle mileage was only 302 billion miles, but by 1978 mileage had increased five

TABLE 26--U.S. ENERGY CONSUMPTION BY FUEL TYPE, 1850-1980 (IN QUADS) (1)

Year	Total	Coal	Natural Gas	Petroleum	Hydro-power	Nuclear Power	Fuel Wood
1850	2.3	.2					2.1
1860	3.1	.5					2.6
1870	4.0	1.0					2.9
1880	5.0	2.0		.1			2.9
1890	7.1	4.1	.3	.2			2.5
1900	9.6	6.8	.3	.2	.3		2.0
1910	16.6	12.7	.5	1.0	.5		1.9
1920	21.3	15.5	.8	2.6	.8		1.6
1930	23.3	13.6	2.0	5.4	.8		1.5
1940	25.0	12.5	2.7	7.5	.9		1.4
1950	35.2	12.9	6.2	13.5	1.4		1.2
1960	44.6	10.1	12.7	20.1	1.7		
1970	67.1	12.7	22.0	29.5	2.7	.2	
1977	76.3	14.1	19.9	36.9	2.5	2.7	
1979	78.9	15.1	20.5	37.3	3.2	2.7	
1980	76.1	15.6	20.4	34.3	3.1	2.7	
1981	73.9	15.9	19.9	31.9	3.1	2.9	
1982	71.0	15.4	18.5	30.4	3.6	3.1	

Data do not include energy developed by animals, windmills, watermills, waterwheels, etc. In 1920, there were 25 million draft animals supplying power for industry, agriculture, and transportation.

Details may not add to total due to rounding.

(1) One quad equals one quadrillion British thermal units (Btu). One Btu is the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit at or near its point of maximum density.

Sources:

1850-1970: U.S. Department of the Interior. Energy Perspectives, February 1975, p. 34.

Monthly Energy Review, December 1978, p. 12.
1979: U.S. Department of Energy. Energy Information Administration. Monthly Energy Review, October 1980, p. 6.
1980: U.S. Department of Energy. Energy Information Administration. Monthly Energy Review. February 1981. p. 8.
Monthly Energy Review, December 1983.

fold to over 1.5 trillion miles (table 27). Pesticide production in 1950 was only 286 million pounds; however, by 1981 pesticide production reached 1.4 billion pounds; a 5-fold increase (table 28). Certainly, the growth portrayed by these data suggest that, if uncontrolled, energy consumption and product development can have serious implication for the environment.

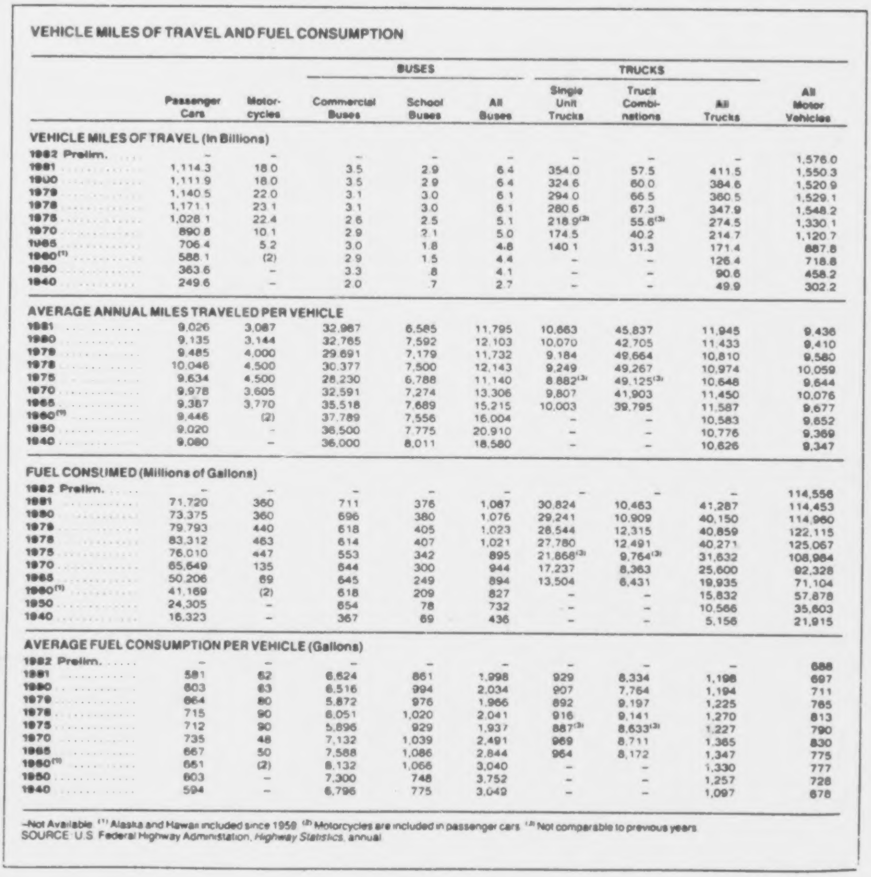
In technical and political terms, the environment and energy are often cast in tradeoff terms, where choices must be made between a clean environment and the mobility, energy, and products of contemporary life. In practice, resource consumption and environmental degradation are, in many respects, the two sides of the same issue. Resource use is the key to modern technology, industrial growth, and human comfort; but resource consumption is also the principal source of modern-day pollution.

MARKET FAILURE

For over two hundred years, economics has been a dominant force in shaping and governing the goals, priorities, and the social structure of the Nation. Regulations have played an important role in achieving these objectives; however, the increased use of regulation is disquieting to many.

The U.S. economy is commonly described as a free enterprise system and within this system prices allocate the use of resources. Economics has always concerned itself with two factors of production: labor, and capital; however, land (including natural resources and the environment) was largely absent from the production functions in economic analysis. Investment decisions of profit maximizing firms and individuals are predicated on the direct costs that are incurred and the revenues collected. When an investing

TABLE 27



VEHICLE MILES OF TRAVEL AND FUEL CONSUMPTION

			BUSES			TRUCKS			
	Passenger Cars	Motor-cycles	Commercial Buses	School Buses	All Buses	Single Unit Trucks	Truck Combi-nations	All Trucks	All Motor Vehicles
VEHICLE MILES OF TRAVEL (In Billions)									
1982 Prelim.	–	–	–	–	–	–	–	–	1,576.0
1981	1,114.3	18.0	3.5	2.9	6.4	354.0	57.5	411.5	1,550.3
1980	1,111.9	18.0	3.5	2.9	6.4	324.6	60.0	384.6	1,520.9
1979	1,140.5	22.0	3.1	3.0	6.1	294.0	66.5	360.5	1,529.1
1978	1,171.1	23.1	3.1	3.0	6.1	280.6	67.3	347.9	1,548.2
1975	1,028.1	22.4	2.6	2.5	5.1	218.9[3]	55.6[3]	274.5	1,330.1
1970	890.8	10.1	2.9	2.1	5.0	174.5	40.2	214.7	1,120.7
1965	706.4	5.2	3.0	1.8	4.8	140.1	31.3	171.4	887.8
1960[1]	588.1	(2)	2.9	1.5	4.4	–	–	126.4	718.8
1950	363.6	–	3.3	.8	4.1	–	–	90.6	458.2
1940	249.6	–	2.0	.7	2.7	–	–	49.9	302.2
AVERAGE ANNUAL MILES TRAVELED PER VEHICLE									
1981	9,026	3,087	32,987	6,585	11,795	10,663	45,837	11,945	9,436
1980	9,135	3,144	32,765	7,592	12,103	10,070	42,705	11,433	9,410
1979	9,485	4,000	29,691	7,179	11,732	9,184	49,664	10,810	9,580
1978	10,046	4,500	30,377	7,500	12,143	9,249	49,267	10,974	10,059
1975	9,634	4,500	28,230	6,788	11,140	8,882[3]	49,125[3]	10,648	9,644
1970	9,978	3,605	32,591	7,274	13,306	9,807	41,903	11,450	10,076
1965	9,387	3,770	35,518	7,689	15,215	10,003	39,795	11,587	9,677
1960[1]	9,446	(2)	37,789	7,556	16,004	–	–	10,583	9,652
1950	9,020	–	36,500	7,775	20,910	–	–	10,776	9,369
1940	9,080	–	36,000	8,011	18,580	–	–	10,626	9,347
FUEL CONSUMED (Millions of Gallons)									
1982 Prelim.	–	–	–	–	–	–	–	–	114,556
1981	71,720	360	711	376	1,087	30,824	10,463	41,287	114,453
1980	73,375	360	696	380	1,076	29,241	10,909	40,150	114,960
1979	79,793	440	618	405	1,023	28,544	12,315	40,859	122,115
1978	83,312	463	614	407	1,021	27,780	12,491	40,271	125,067
1975	76,010	447	553	342	895	21,868[3]	9,764[3]	31,632	108,984
1970	65,649	135	644	300	944	17,237	8,363	25,600	92,328
1965	50,206	69	645	249	894	13,504	6,431	19,935	71,104
1960[1]	41,169	(2)	618	209	827	–	–	15,832	57,878
1950	24,305	–	654	78	732	–	–	10,566	35,603
1940	16,323	–	367	69	436	–	–	5,156	21,915
AVERAGE FUEL CONSUMPTION PER VEHICLE (Gallons)									
1982 Prelim.	–	–	–	–	–	–	–	–	688
1981	591	62	6,624	861	1,998	929	8,334	1,198	697
1980	603	63	6,516	994	2,034	907	7,764	1,194	711
1979	664	80	5,872	976	1,966	892	9,197	1,225	765
1978	715	90	6,051	1,020	2,041	916	9,141	1,270	813
1975	712	90	5,896	929	1,937	887[3]	8,633[3]	1,227	790
1970	735	48	7,132	1,039	2,491	969	8,711	1,365	830
1965	667	50	7,588	1,086	2,844	964	8,172	1,347	775
1960[1]	661	(2)	8,132	1,066	3,040	–	–	1,330	777
1950	603	–	7,300	748	3,752	–	–	1,257	728
1940	594	–	6,796	775	3,049	–	–	1,097	678

–Not Available [1] Alaska and Hawaii included since 1959 [2] Motorcycles are included in passenger cars. [3] Not comparable to previous years.
SOURCE: U.S. Federal Highway Administration, *Highway Statistics*, annual.

Source: MVMA Motor Vehicle Facts and Figures. 1983.

Pesticide production,[1] by type, 1950–1981

(million pounds)

Table 28
Toxic substances

Year	Synthetic organic pesticides: Total	Herbicides	Insecticides [2]	Fungicides
1950	286	*NA*	*NA*	*NA*
1951	464	*49*	*319*	96
1955	506	*NA*	*NA*	*129*
1960	648	*102*	*366*	*179*
1961	700	*121*	*411*	*168*
1962	730	*151*	*461*	*117*
1963	763	*175*	*478*	*111*
1964	783	*226*	*444*	*113*
1965	877	*263*	*490*	*124*
1966	1,013	*324*	*552*	*137*
1967	1,050	*409*	*496*	*144*
1968	1,192	*469*	*569*	*154*
1969	1,104	*393*	*571*	*141*
1970	1,034	*404*	*490*	*140*
1971	1,136	*429*	*558*	*149*
1972	1,158	*451*	*564*	*143*
1973	1,289	*496*	*639*	*154*
1974	1,417	*604*	*650*	*163*
1975	1,603	*788*	*660*	*155*
1976	1,364	*656*	*566*	*142*
1977	1,388	*674*	*570*	*143*
1978	1,416	*664*	*605*	*148*
1979	1,429	*657*	*617*	*155*
1980	1,468	*806*	*506*	*156*
1981	1,430	*839*	*448*	*143*

Details may not add to total due to independent rounding
NA—Not available.

[1] Production data include the total quantity of a commodity made available by the *original* manufacturers only. Production excludes intermediate products in the manufacturing process.

[2] Insecticides include fumigants, rodenticides, and soil conditioners.

Source: U.S. International Trade Commission, *Synthetic Organic Chemicals, United States Production and Sales, 1981* (Washington: USGPO, 1981), and previous annual issues.

firm cannot capture all benefits, society is the recipient in the form of these external benefits. Conversely, when damages to the public are not incorporated in the cost production, the damages are borne by society. These external benefits and damages, or externalities, are prime examples of the failure of the market system to allocate resources efficiently. 67/

Economists, more often than not, use the free market system as the basis for resource allocation; and therefore it is understandable that many economists seek to utilize this system for managing the environment. Effluent taxes, or charges, are suggested to be the solution to environmental degradation. The argument goes that charges would provide an incentive to abate pollution quickly by imposing an immediate economic cost on the discharger of pollutants. This cost would reflect the price of the heretofore free air and and water resources, and this action would reduce the damages to society. 68/

Congressional scrutiny of the regulatory and effluent charge approach to pollution control took place during the debate or S. 2770, which was enacted as the Federal Water Pollution Control Act Amendments of 1972. Senator Proxmire proposed an amendment that would have established effluent charges for all effluents other than municipal sewage. He listed the following advantages of his amendment:

67/ For a more complete treaties or market failure, see: Bator, F.M. The Anatomy of Market Failure. Quarterly Journal of Economics. August 1958. pp. 351-79.

68/ For a more complete treatment of effluent charges see U.S. Congress. Senate. Committee on Environment and Public Works. Pollution Taxes, Effluent Charges, and Other Alternatives for Pollution Control. Committee Print Serial No. 95-5. Washington, D.C. U.S. Government Printing Office. May 1977.

> First. They give industry an incentive to abate at the source, by supplying the profit advantage. The effluent charges cannot become a license to pollute as long as the charge is set higher than the cost of abatement--which the amendment would do.
>
> This is the reason why the conservation organizations which had opposed this approach in the past now support it. They have testified before the Joint Economic Committee. They have gone on record clearly in support of this kind of economic incentive, because they now appreciate and support the fact that the charge can be set at a level which can effectively reduce pollution and do it very rapidly.
>
> Second. This is a fair and equitable method. The one who pollutes should pay not the Federal taxpayer at large.
>
> Third. In the third place, the incentive is continuing; it operates even after standards are met. As new technology comes along, it may become possible to abate to even lower levels than we now have any right to expect. Effluent charges will compel industry to continue to seek out new technology, new ways of avoiding the change...
>
> Fourth. Mr. President, I think the principal argument for this is that it works. It has been tried in a number of cities, and in each case it has abated pollution very rapidly, within a matter of months. 69/

Senator Muskie made the following observations with respect to Senator Proxmire's presentation:

> First, with respect to the question of enforcement, adoption of the Proxmire amendment would not eliminate an enforcement problem. Even a tax must

---

69/ U.S. Congress. Senate. Committee on Public Works. A Legislative History of the Water Pollution Control Act of 1972. Committee Print. Volume 2, 93d Cong., 1st sess. U.S. Govt. Print. Off., Washington, D.C. p. 1319.

> be enforced. At least, my impression of the existence of the Internal Revenue Service and the large number of employees it has suggests that enforcement can be a full-time job. So, whether we enforce an effluent fee or a no-discharge policy of effluent controls, we are going to need enforcement.
>
> Adoption of the Proxmire amendment to this legislation would not eliminate the need for enforcement. It would add another requirement for enforcement. That is an important thing to remember.
>
> With respect to effluent fees, it is important to note that effluent fees are a mechanism of effluent reduction, not effluent control. A pollutor will control his discharges only to the degree that such control is cheaper than the fee--exploiting marginal economics.
>
> If the degree of control achieved is adequate to implement effluent standards, the effluent fee is a useful means to implement existing public policy--if less control is achieved, then the fee is a license to pollute.
>
> There is an underlying assumption that the fee will be set high enough to encourage corresponding investment in pollution control facilities in order to reduce costs. It can be argued that this would only be true if the fee were sufficient to cause plant closure if control were not implemented, in which case the pollutor would either control or close down.
>
> Questions should also be raised as to: first, uniformity of the fee--same fee for similar wastes, all rivers? Second, basis of assessment? Third, the question of the trust fund. 70/

The amendment was defeated.

70/ Ibid., p. 1322.

While Congress has not adopted pollution charges or taxes as central components of pollution control, nevertheless, some individuals continue to support the role of charges. Steven Kelman states that the argument that one can achieve a given level of pollution control more cheaply by using charges remains "unassailed." 71/ Robert Hamrin cautions, however, that there are some real disadvantages to charges. First, there are a host of real-life implementation problems which are not addressed by theory. The tax may not capture all costs of pollution and an insufficient amount of compliance will result. Firms could continue to make suboptimal decisions between compliance and paying a tax. Probably the most basic problem is the lack of sufficient data to set emission charges equal to the damages placed on society by each polluter's waste. 72/

The "charges" approach argument for environmental enhancement has been largely replaced with the offset program. In 1976 EPA established the offset program which allowed certain internal trade-offs on a case-by-case basis. Pollution increases were allowed if compensating offset reductions were found from other sources. This program had been expanded to include the bubble policy, emissions banking, trading, and netting. The courts have rejected part of the relaxed policies and have cast doubt on the fate of these programs. EPA's revised policies have not been received enthusiastically by some business groups. The U.S. Chamber of Commerce's director

---

71/ Kelman, Steven. What Price Incentives? Economists and the Environment. Auburn House Publishing Company. Boston Mass. 1981.

72/ Hamrin, Robert. Environmental Quality and Economic Growth. The Council of State Planning Agencies. Washington, D.C. 1981.

of environment and land resources, Harvey Alter, charged that the policy is basically unsound and only leads to more paperwork. Mr. Alter stated, "technology got us into this mess and only technology can get us out." 73/ He adds:

> If you just let industry install the best available control technology, you'll get cleaner air. But these new schemes won't. It's just putting a Band-aid on the wound and not correcting the baseline problems. 74/

COSTS

In the Clean Air and Clean Water Acts, Congress mandated the Administrator of EPA to make and report detailed estimates of the costs of carrying out the Clean Air Act and the Clean Water Act. These EPA estimates differ from those prepared elsewhere in that the EPA estimates include only those costs required by the respective Acts. The estimates are engineering-type estimates based on assumed levels of accomplishment. The estimates also reflect differences in definition of the industries. EPA acknowledges that its estimates are an overstatement of costs because "no allowances are made for in-process changes or technological innovation, either of which might reduce the costs of pollution control." 75/

The Bureau of Economics Analysis (BEA) in the U.S. Department of Commerce annually publishes the results of a survey of detailed capital expenditures for

---

73/ A Court Pricks EPA's Bubble. Chemical Week. August 25, 1982. p. 17.

74/ A Court Pricks EPA's Bubble. Chemical Week. August 25, 1982. p. 18.

75/ U.S. Congress. Senate. The Cost of Clean Air and Clean Water. Document No. 96-38. 96th Congress. 1st Session. Washington, D.C. U.S. Government Printing Office. December 1979. p. iv.

air, water and solid waste pollution abatement. The survey asks for cost information for total plant and equipment expenditures for pollution abatement, including those not attributed to Federal legislation. One major problem with the BEA survey is how it samples company enterprises. For example a company is categorized by its major product. Thus, a large petroleum company, if it owns a textile mill, would include the investment for pollution control in all plants under petroleum refining. While the information is useful, individual industry specific estimates reveal little about costs to a specific industrial process.

The Bureau of Census, also in the Department of Commerce, publishes the results of their annual survey of manufacturers detailing both capital costs and operating costs for pollution abatement. The survey asks for total expenditures, not just those due to Federal regulations. Unlike the BEA survey, the Census survey is based on plant/or establishment classification.

The methodology for the annual survey of the McGraw-Hill Publications Company has not been revealed, and thus it is difficult to compare with other estimates.

The Council on Environmental Quality began a series of annual estimate with the 1971 Annual report. CEQ estimates were based largely on EPA's edition of the "Cost of Clean Water" and the "Economics of Clean Air". CEQ cautioned that "estimating current and prospective costs to meet environmental objectives is a hazardous exercise." 76/ CEQ had included total abatement costs estimates

---

76/ Environmental Quality. The Second Annual Report of the Council of Environmental Quality. Washington, D.C. U.S. Government Printing Office. 1071. p. 108.

as "a measure of national resources which must be used to meet environmental goals and are therefore unavailable for other uses" 77/ Although total costs are an important indication of the level of resources that the Nation devotes to preventing environmental degradation, they do not focus on the "factors of primary importance to the decisionmaker--the extra costs associated with new programs to improve environmental quality." 78/

The early reports of CEQ cautioned that the estimates were likely to be significant overstatements of true costs; however, the 1974 report recognizing the possibility of substituting process-change for end-of-the-pipe treatment could decrease capital requirements and therefore the estimates presented could represent both the total end incremental costs of pollution abatement. 79/ The 1975 report states:

> This year we set forth to set forth to rectify the imbalance by presenting similarly extensive analyses of damage, avoidance, and transactions costs. Unfortunately, there is still simply too little information available to provide the balance needed. Abatement costs have been quantified extensively, but too little is known about damage costs for them to be estimated with reasonable confidence. Some information is available on transactions costs, but almost no estimates have been made of avoidance costs.
>
> It is disturbing to remain in such a state of ignorance about the various costs and benefits associated with programs to safeguard the environment. Although as a nation we are committed to

---

77/ Environmental Quality. 1972. p. 275.

78/ Environmental Quality. 1973. p. 100.

79/ Environmental Quality. 1975. p. 222.

> large expenditures, we do not know whether we are spending too much or too little. 80/

The 1976 report stated, "[T]his year's estimates of pollution abatement costs are essentially the same as last year's." 81/ The 1977 report assessment of the impact of environmental programs is as follows: macroeconomic analyses sponsored by CEQ and EPA indicate that environmental programs are not expected to have a major impact on the economy." 82/

A study completed for CEQ and discussed in the 1978 report suggests that considerable amount of the expenditures for pollution abatement are made just to keep the environment from being degraded more than it currently is. The report states:

> A particularly interesting implication of the projections shown in the figure is that a large portion of the environmental improvement effort (particularly in terms of pollution control expenditures) is simply preventing deterioration beyond 1970 levels. CEQ's analysis of pollution abatement costs suggest that "more than one-half of these expenditures are made just to keep the environment from becoming more degraded than it already is." 83/

80/ Environmental Quality. 1975. p. 496.

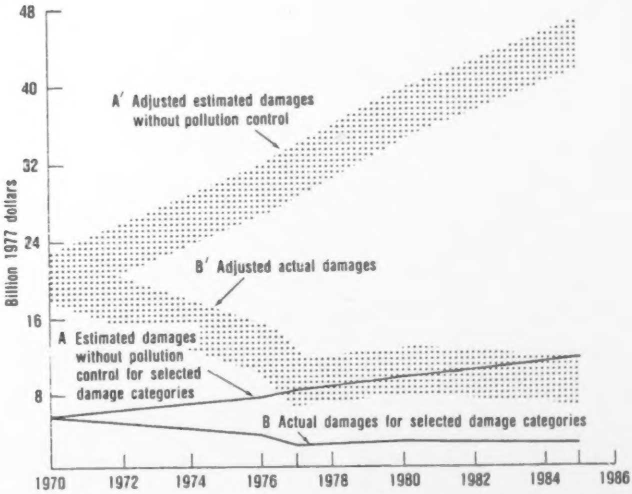
81/ Environmental Quality. 1976. p. 144.

82/ Environmental Quality. 1977. p. 332.

83/ Environmental Quality. 1978. p. 420.

Figure B

Estimated Annual Air Pollution Damage Costs 1970-86



Source: Thomas E. Waddell, "Preliminary Update and Projections of Selected Categories of Damage Cost Estimates," prepared for the Council on Environmental Quality, May 1978.

As reproduced in Environmental Quality. 1978. p. 421.

"In some important respects, the CEQ estimates may exaggerate pollution control and environmental quality spending." 84/ CEQ reports that estimates of industrial compliance assumes installation of specific technology and furthermore, projections of the number of new sources may cause overestimation. The 1980 report cautions:

> Because of their high level of aggregation, however, the CEQ estimates cannot be used to evaluate the benefits and costs of specific standards or provisions of the Clean Air Act, the Clean Water Act, or similar legislation. 85/

It adds:

> There is a great deal of uncertainty in these estimates. Although they are presented as point estimates (that is, as single numbers), they might better be presented as ranges because of the uncertainties involved in determining them. 86/

The 12th Annual Report of CEQ deviated from the format of the previous reports in that no environmental economics section was included. The Annual report did present estimates by BEA, Census and OMB in the Appendix to the report. Nonetheless, the report expressed its dissatisfaction with past and current economic policies. It stated:

84/ Environmental Quality. 1979. p. 663

85/ Environmental Quality. 1980. p. 393

86/ Environmental Quality. 1980. p. 396

> In the past, marketplace forces have not been sufficiently applied to determine either the use of publicly owned natural resources or to control the degradation of the environmental commons. In fact, since the Administration of President Franklin D. Roosevelt, such thinking has all but fallen out of fashion. Instead, the Federal Government has tended to make large-scale economic value judgments, in favor of river basin development, for example, which often have contributed inadvertently to the deterioration of the environment. 87/

It added:

> Legislation in the 1970s began to force parties to recognize environmental costs explicitly. The Clean Air Act, the Clean Water Act, and the Surface Mining Act, among others, enforced pollution standards that required potential emitters either to limit charges of pollutants into the commons or to restore the commons after disruption. The costs of avoiding or ameliorating environmental damage thus were forcibly internalized by the private sector...
>
> Despite the best of intentions, past experience with the environmental legislation of the 1970s has demonstrated that an overly rigid attempt to internalize environmental costs may impose other costs that are out of proportion to the benefits accruing to society...
>
> In the 1980s the costs involved in using public resources in the course of private business or individual consumption should be made explicit. For example, the cost of disposing of hazardous wastes should be paid through increased user rates by the customers of the industries that create those wastes. Only if the costs of public resource use are internalized explicitly will those resources be used most efficiently. Environmental standards should be set based upon the environment's natural assimilative capacity, scientifically verified health needs, and the economic well-being of the nation

---

87/ Environmental Quality. 1981. p. 17.

> as a whole. The private sector should then be encouraged to attain such environmental standards in the most cost-effective manner. An economic system which recognizes the costs of using natural resources and the cost of controlling adverse environmental effects, and which attempts to balance these costs with the benefits of enhanced human health and efficient economic development will be a strongly ally in both the short and long-term conservation of natural resources. 88/

In short, the cost studies undertaken during the past decade provide information to complete various statistical series, e.g., national income accounting and census. The estimates by CEQ, according to their own assessment, are too crude and unreliable to be used in benefit-cost analysis and other attempts at resolving the debates. The projected cumulative estimates developed by CEQ have no counterparts in other sector analyses.

A NEW CONCERN FOR EFFICIENCY

The general public, economists, and policy makers are all in agreement that efficiency is a desirable goal. Many individuals call for reduced expenditures for pollution abatement in the search for efficiency. Cost-effectiveness and benefit-cost analysis are held as the solution to alleged excessive expenditures. New and old economic incentives are proposed and reproposed to entice industry to be responsive to environmental regulation. Most proposals are directed at short-term solutions to immediate problems. Often the large industrial polluter objects to

---

88/ Environmental Quality. 1981. p. 16-17.

proposals for effluent taxes and other charges. Increasingly, industry is looking for long-term solutions to environmenal degradation that are in concert with other production goals. Studies by BEA indicate that changes-in-production processes (CIPP) has been steadily increasing. CIPP amounted to 17 percent of total pollution control expenditures in 1975 and has risen slowly and steadily, reaching 28.9 percent in 1981, 30.9 percent in 1982, and 31.23 percent in 1983. This approach has a great potential for reducing environmental degradation. CIPP is an integral part of industries response to environmental regulations.

The "Pollution Prevention Pays" program (3P program) established by the 3M Company is illustrative of CIPP. The 3P program stresses the use of low and non-waste technical innovations. The 3M Company introduced the program in 1975 to reduce the amount of resources, manpower and money required to comply with environmental laws and regulations. 89/ The 3P program materialized from a comprehensive effort to encourage pollution prevention. Employees are encouraged to seek solutions through:

1. Product reformulation
2. Process modification
3. Equipment redesign
4. Recovery of waste material for reuse. 90/

The success of the program over the first six years is shown below:

89/ Lehr, Lewis W. Pollution Prevention Pays: 3M Company Encourages Technology That Will Prevent Pollution, Not Just Control It. Catalyst Vol. VI. No. 3. 1978. pp. 14-18.

90/ Low-and Non-Pollution-Technology Through Pollution Prevention: an Overview. Prepared by the 3M Co. For the United Nations Environment Programme.

> Recognition was provided to 545 projects in 20 countries. These produced a total saving of $97 million. These savings include $76.5 million from U.S. Operations and $20.5 million from International Operations.
>
> In the U.S., 3P savings included: $19 million for pollution-control equipment and facilities which were delayed or eliminated; $42.3 million for pollution-control operating costs; $4.2 million for energy savings not included in operating costs, and $11 million for sales retained of products which otherwise might be taken off the market as environmentally unacceptable.
>
> Each year, the 3P Program prevents the creation of these pollutants:

	U.S.	International
Air Pollutants	123,000 tons	4,000 tons
Water Pollutants	4,000 tons	150 tons
Wastewater	900 million gal.	279 million gal.
Sludge/Soild Waste	12,000 tons	1,500 tons

> The program also produces an estimated annual energy conservation of 1.2 trillion Btu, or the equivalent of 228,000 barrels of petroleum.
>
> Projects have ranged from improved control of process coating weight at Gorseinon, Wales, and recycling of wastewater at Hilden, Federal Republic of Germany, to a variety of combustion-control and heat-recovery processes in Japan. Among the larger projects was a process change in the United States that solved an order problem, and eliminated the need for a $1 million thermal oxidizer and $50,000 annually to fuel and operate the oxidizer.

According to 3M Company, application of projects of this type requires cooperation between industry and the government and mutual understanding of environmental realities:

1. The issue is real but emotional;
2. The decisions are political;
3. The solutions are economic and technical

According to 3M, to foster, this development, government should:

1. Support basic research in universities and research institutes;
2. Create and support national laboratories;
3. Allow deductibility of research and development expenditures for computing income taxes at some multiple of the actual outlay;
4. Allow firms to take research and development expenditures as a tax credit rather than a deduction as a business expense;
5. Divert more federal research and development to industry;
6. Fund demonstration plants. 91/

The 3M experience indicates that government support and encouragement of a low-and non-pollution technology program would not only enhance environmental goals, but would merge them with social and economic objectives.

91/ Low-and Non-Pollution Technology. Ibid., p. 14.

SELECTED READINGS

COST SURVEYS

Pollution Abatement and Control Expenditures, 1972-81

REAL expenditures for pollution abatement and control (PAC) declined 1 percent in 1981 (chart 4).[1] The revised estimate for 1980 also showed a decline. In 1972-79, expenditures had increased each year, at an average annual rate of 5½ percent. Pollution abatement (PA) expenditures, the largest category of PAC expenditures, declined (in 1972 dollars) 1 percent in 1981; regulation and monitoring increased less than 1 percent; and research and development declined 3 percent.

This article first presents and discusses PAC estimates for recent years: real expenditures and prices of PAC goods and services in 1981, the limited data on expenditures available for 1982, and revisions in PAC estimates for 1978-80. Next, it summarizes trends for 1972-81 in air and water PA expenditures. Finally, it introduces estimates of business PAC costs, which are designed to facilitate analysis that is more comprehensive than could be undertaken previously.

NOTE.—Estimates of business PAC costs, presented in this article for the first time, are a result of research by Frederick J. Dreiling on the GNP-account treatment of PAC.

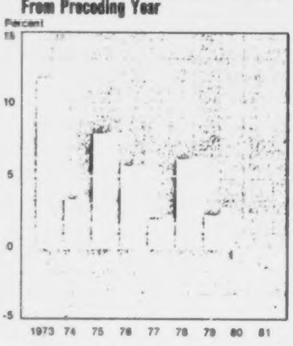
Estimates for recent years

PAC expenditures are classified in table 1 by type (e.g., water PAC), function (e.g., research and development), sector (e.g., business), and accounting category (e.g., on capital account). Table 2 shows additional detail for business and government expenditures for air and water pollution abatement (most of PAC). Table 3 shows expenditures for aspects of solid waste management, including, but not limited to, collection and disposal. Table 4 shows price changes for total PAC expenditures and selected components.

Real PAC spending in 1981.—In absolute terms, the 1981 decrease in total PAC spending was $0.3 billion (in 1972 dollars) and was due to a large decrease in water PAC. Water PAC spending decreased $1.4 billion, or 12½ percent. Air PAC spending increased $0.9 billion, or 7½ percent; solid waste disposal spending increased $0.2 billion, or 4 percent; and "other and unallocated" spending increased slightly.

CHART 4

Real PAC Expenditures: Percent Change From Preceding Year



U.S. Department of Commerce, Bureau of Economic Analysis

83-2-4

The largest absolute changes in air and water PAC spending were for PA capital (see accompanying tabulation). For water, each major category of capital spending again decreased. Public sewer systems construction spending (government enterprise fixed capital) decreased $1.0 billion, or 23 percent, the third consecutive decrease. Plant and equipment spending by business decreased $0.3 billion, or 16½ percent, the fifth decrease. Spending for septic systems and connectors to public sewers (residential systems) decreased $0.1 billion, the third decrease.

[Change in 1981, billions of 1972 dollars]

Total expenditures for PAC	−.3
Water PA	−1.4
Capital	−1.4
Public sewer systems	−1.0
Plant and equipment	−.3
Residential systems	−.1
Current account	.1
Air PA	.9
Capital	.8
Motor vehicle emission abatement	1.1
Plant and equipment	−.3
Current account	.1
Solid waste disposal	.1
Capital	0
Current account	.1
Other	0

The large decrease in spending for construction of public sewer systems was due to decreases in related Federal grants-in-aid and in State and local funding for sewer systems. The decrease in Federal grants-in-aid for sewer systems was the first significant one since 1978 and was part of a slowdown in these grants since 1977 (table 5). (See the accompanying box for a background discussion of these grants.) The decrease in State and local funding in 1981, the largest since these decreases began in 1979, was due to record high interest rates on municipal bonds, taxpayer's increased sensitivity to growth in government, and reduced housing construction requiring connection to sewer systems. The decrease in recent years in construction of public sewer systems is part of a general trend for State and local total construction.

---

[1] PAC expenditures are for the reduction of pollutant emissions and the collection and disposal of solid wastes by means acceptable to Federal, State, and local authorities. PAC expenditures consist of those for pollution abatement, which reduce pollutant emissions directly, plus expenditures for regulation and monitoring and for research and development, which lead indirectly to the reduction of emissions. Expenditures for other aspects of environmental control, such as expenditures for natural resource conservation or protection of endangered species, are excluded. Pollutants are defined as substances and other emissions (e.g., noise) that degrade the quality of air or water shared by all.

For air, spending for motor vehicle emission abatement devices (consumer and business spending) increased $1.1 billion, or 31 percent, after increasing each year since 1972. A decrease in plant and equipment spending of $0.3 billion, or 11½ percent, was a partial offset.

Motor vehicle emission abatement spending increased, despite a decrease in unit sales of cars, due to the addition of expensive computer-like electronic equipment to regulate engine operation and emissions. This equip-

Table 1.—Expenditures for Pollution Abatement and Control in Current

	Line	1972	1973	1974	1975	1976	1977	1978[r]				
		Total	Total	Total	Total	Total	Total	Total	Air	Water	Solid waste	Other and unallocated[2]
Millions of												
Pollution abatement and control	1	18,434	21,930	26,261	30,922	34,681	37,962	43,416	17,324	19,877	6,608	−394
Pollution abatement[1]	2	17,245	20,537	24,678	29,167	32,677	35,652	40,833	16,117	19,253	6,518	−1,055
Personal consumption	3	1,536	2,065	2,667	3,463	3,994	4,311	4,762	4,762			
Durable goods	4	476	670	690	1,361	1,821	2,166	2,525	2,525			
Nondurable goods and services	5	1,060	1,395	1,977	2,102	2,173	2,145	2,237	2,237			
Business	6	10,960	13,097	15,527	18,134	20,335	22,761	25,692	11,072	11,215	4,479	−1,075
On capital account	7	5,399	6,766	7,436	8,832	9,469	10,101	10,883	5,317	4,984	582	
On current account	8	5,561	6,331	8,091	9,302	10,866	12,660	14,809	5,755	6,231	3,897	−1,075
Private	9	4,838	5,459	6,994	8,100	9,532	11,022	12,833	5,683	3,253	3,897	
Government enterprise	10	1,151	1,342	1,635	1,895	2,221	2,603	3,051	72	2,978	(*)	(*)
Costs recovered	11	−428	−470	−538	−693	−887	−965	−1,075				−1,075
Government	12	4,749	5,375	6,484	7,570	8,348	8,580	10,380	283	8,038	2,039	20
Federal	13	139	208	294	432	472	490	472	90	316	47	19
State and local	14	1,311	1,433	1,591	1,752	1,834	1,963	2,212	(*)	218	1,992	1
Government enterprise fixed capital	15	3,299	3,738	4,599	5,387	6,042	6,128	7,697	193	7,504		
Regulation and monitoring	16	367	490	595	653	725	832	949	276	405	55	213
Federal	17	200	278	345	381	402	429	507	93	186	27	201
State and local	18	167	212	248	272	323	404	442	183	219	28	12
Research and development	19	823	903	988	1,103	1,279	1,478	1,633	931	219	35	449
Private	20	519	560	606	608	706	849	985	777	99	16	93
Federal	21	205	278	342	448	528	578	592	146	104	16	326
State and local	22	99	66	39	47	45	51	57	8	17	4	29
Millions of constant												
Pollution abatement and control	23	18,434	20,602	21,307	23,008	24,325	24,800	26,330	10,185	11,963	4,342	−150
Pollution abatement[1]	24	17,245	19,296	19,951	21,644	22,867	23,230	24,696	9,432	11,564	4,284	−574
Personal consumption	25	1,536	1,965	2,116	2,589	2,857	2,945	3,066	3,066			
Durable goods	26	476	670	651	1,184	1,489	1,683	1,816	1,816			
Nondurable goods and services	27	1,060	1,295	1,465	1,406	1,368	1,262	1,250	1,250			
Business	28	10,960	12,330	12,372	13,057	13,789	14,315	15,011	6,204	6,465	2,939	−586
On capital account	29	5,399	6,435	6,200	6,662	6,762	6,760	[illegible]	3,384	3,028	346	
On current account	30	5,561	5,895	6,172	6,395	7,027	7,555	[illegible]	2,820	3,428	2,593	−586
Private	31	4,838	5,039	5,259	5,520	6,138	6,550	7,136	2,792	1,751	2,593	
Government enterprise	32	1,151	1,263	1,296	1,330	1,444	1,574	1,706	28	1,676	(*)	(*)
Costs recovered	33	−428	−407	−383	−456	−555	−569	−587				−587
Government	34	4,749	5,002	5,463	5,998	6,221	5,970	6,619	163	5,099	1,345	12
Federal	35	139	190	245	332	338	323	[illegible]	48	198	30	11
State and local	36	1,311	1,330	1,305	1,344	1,349	1,359	1,418	(*)	102	1,315	1
Government enterprise fixed capital	37	3,299	3,482	3,913	4,322	4,534	4,288	4,913	115	4,799		
Regulation and monitoring	38	367	456	515	517	538	577	620	179	262	36	142
Federal	39	200	259	303	305	305	304	340	62	125	19	134
State and local	40	167	197	212	213	234	274	280	116	139	17	8
Research and development	41	823	849	840	847	920	993	1,014	574	137	22	282
Private	42	519	535	512	461	501	562	604	476	61	10	57
Federal	43	205	253	294	348	385	394	373	92	65	10	206
State and local	44	99	61	34	38	35	37	38	5	11	3	19
Selected implicit												
Pollution abatement and control	45	100.0	106.4	123.3	134.4	142.6	153.1	164.9	170.1	166.3	152.2	262.7
Pollution abatement	46	100.0	106.4	123.7	134.8	142.9	153.5	165.3	170.9	166.6	152.2	182.8
Personal consumption	47	100.0	105.1	126.0	133.8	139.8	146.4	155.3	155.3			
Business	48	100.0	106.2	125.5	138.9	147.5	159.0	171.2	178.5	173.7	152.4	183.2
On capital account	49	100.0	105.1	119.9	132.6	140.0	149.4	161.0	157.1	164.6	168.2	
On current account	50	100.0	107.4	131.1	145.5	154.6	167.6	179.4	204.1	181.8	150.3	183.2
Government	51	100.0	107.4	118.7	126.2	134.2	143.7	156.8	173.4	157.6	151.6	163.6
Regulation and monitoring	42	100.0	107.4	115.4	126.2	134.8	144.2	153.2	154.8	154.0	153.5	149.7
Research and development	53	100.0	106.4	117.6	130.3	139.0	148.9	161.0	162.3	159.9	159.3	159.0
Addendum: Business capital consumption												
Valued at replacement cost in current dollars	54	1,831	2,196	2,830	3,578	4,282	5,061	5,911				
Valued at replacement cost in constant (1972) dollars	55	1,831	2,094	2,301	2,713	3,066	3,413	3,721				

r Revised.

p Preliminary.

* Less than $500,000.

1. Includes expenditures for air and water pollution abatement and control. Includes expenditures for solid waste collection and disposal by means acceptable to Federal, State, and local authorities. Excludes agricultural production except feedlot operations.

2. "Other" includes expenditures for abatement and control of noise, radiation, and pesticide pollution; "unallocated" includes business expenditures not assigned to media.

3. Expenditures are attributed to the sector that performs the air or water pollution abatement or solid waste collection and disposal.

4. Current-dollar estimates divided by constant-dollar estimates.

5. To facilitate conversion of expenditures to a cost basis.

ment, the largest added expense per car due to PA since 1968, was designed to help meet tightened emission abatement requirements for 1981 model year passenger cars.

The 1981 decrease in air and water PA plant and equipment spending occurred despite upcoming deadlines for improved PA (1982 for air and 1983-84 for water). Deadlines in the 1980's may be having less effect on the pattern of changes in spending than did similar deadlines in 1970's, when laws setting deadlines were relatively new and postponement of deadlines not yet a regular occurrence.

Within the solid waste category, capital spending remained at the 1980 level. Current-account spending, which has increased each year since 1973, increased $0.1 billion, or 3½ percent.

Prices in 1981.—Price increases slowed in 1981, the first time since 1976, according to the fixed-weighted and chain price indexes for PAC goods and services (table 4). Both indexes increased 9½ percent in 1981,

and Constant Dollars and Selected Implicit Price Deflators [1]

1979r					1980r					1981r					Line
Total	Air	Water	Solid waste	Other and unallocated [2]	Total	Air	Water	Solid waste	Other and unallocated [2]	Total	Air	Water	Solid waste	Other and unallocated [2]	
current dollars															
49,904	21,031	21,799	7,664	-590	56,061	25,606	22,424	8,783	-752	60,326	29,494	21,724	9,971	-863	1
47,062	19,704	21,126	7,536	-1,304	53,003	24,255	21,673	8,606	-1,531	57,154	28,142	20,972	9,668	-1,628	2
5,646	5,646				7,092	7,092				9,011	9,011				3
2,912	2,912				3,715	3,715				5,198	5,198				4
2,734	2,734				3,378	3,378				3,813	3,813				5
30,066	13,691	12,446	5,289	-1,359	34,324	16,690	13,163	6,080	-1,609	37,532	18,630	13,844	6,845	-1,787	6
12,309	6,317	5,268	724		13,099	7,198	5,066	835		13,509	7,892	4,707	910		7
17,757	7,373	7,178	4,566	-1,359	21,225	9,492	8,097	5,245	-1,609	24,023	10,738	9,137	5,935	-1,787	8
15,596	7,267	3,763	4,566		18,747	9,344	4,159	5,245		21,146	10,582	4,629	5,935		9
3,522	106	3,415	(*)	1	4,087	148	3,939	(*)	1	4,665	156	4,508	(*)	1	10
-1,360				-1,360	-1,610				-1,610	-1,788				-1,788	11
11,350	368	8,681	2,246	55	11,587	473	8,511	2,525	79	10,611	500	7,128	2,824	159	12
548	103	347	48	50	496	95	275	55	70	533	94	244	66	129	13
2,461	(*)	257	2,198	6	2,772	(*)	293	2,470	9	3,066	(*)	278	2,758	30	14
8,341	265	8,076			8,321	378	7,943			7,012	406	6,606			15
1,067	300	425	86	257	1,296	329	525	129	313	1,398	334	513	240	311	16
593	100	232	37	225	793	122	326	66	280	840	108	293	153	286	17
474	200	193	49	32	502	207	199	63	34	559	226	220	88	25	18
1,775	1,027	248	43	457	1,762	1,022	226	49	465	1,774	1,018	239	62	454	19
1,143	915	111	15	102	1,107	887	108	14	98	1,102	883	108	14	97	20
564	105	118	24	317	591	130	95	32	335	644	135	121	44	344	21
69	8	19	4	38	64	5	23	3	33	28	(*)	11	4	13	22
(1972) dollars															
26,936	10,748	11,832	4,540	-184	26,730	11,256	11,029	4,643	-199	26,407	12,125	9,650	4,838	-206	23
25,236	9,975	11,422	4,462	-623	25,018	10,504	10,608	4,543	-638	24,721	11,402	9,255	4,678	-615	24
3,100	3,100				3,344	3,344				4,094	4,094				25
1,943	1,943				2,295	2,295				3,025	3,025				26
1,158	1,158				1,049	1,049				1,068	1,068				27
15,651	6,683	6,497	3,124	-653	15,582	6,933	6,129	3,199	-678	15,480	7,083	5,789	3,299	-691	28
6,992	3,705	2,902	386		6,816	3,848	2,571	397		6,510	3,946	2,169	395		29
8,658	2,978	3,596	2,738	-653	8,767	3,085	3,558	2,803	-678	8,970	3,137	3,620	2,904	-691	30
7,531	2,946	1,848	2,738		7,614	3,045	1,766	2,803		7,786	3,098	1,785	2,904		31
1,780	32	1,748	(*)	(*)	1,831	39	1,791	(*)	(*)	1,875	39	1,836	(*)	(*)	32
-653				-653	-678				-678	-691				-691	33
6,486	192	4,925	1,338	30	6,092	228	4,480	1,344	40	5,147	226	3,467	1,378	76	34
297	48	194	28	27	252	43	142	30	36	255	41	116	34	64	35
1,428	(*)	115	1,310	3	1,434	(*)	116	1,314	4	1,470	(*)	114	1,344	12	36
4,761	144	4,617			4,407	185	4,222			3,422	185	3,237			37
653	181	261	52	160	728	180	295	72	181	731	168	267	127	169	38
372	63	145	23	141	459	71	189	38	162	459	59	160	84	156	39
281	118	115	29	19	269	109	107	34	19	272	109	107	44	13	40
1,046	593	149	26	278	984	572	126	27	258	955	555	128	33	240	41
654	523	63	9	58	621	498	61	8	55	604	484	59	8	53	42
349	65	73	15	196	327	72	53	18	185	337	71	63	23	180	43
43	5	12	2	24	35	3	13	2	18	15	(*)	6	2	7	44
price deflators [4]															
185.3	195.7	184.2	168.8	189.8	209.7	227.5	203.3	189.2	213.1	228.4	243.3	225.1	206.1	230.6	45
186.5	197.5	185.0	168.9	207.2	211.9	230.9	204.3	189.4	234.9	231.2	246.8	226.6	206.7	253.7	46
182.1	182.1				212.1	212.1				220.1	220.1				47
192.1	204.9	191.6	169.3	208.2	220.3	240.7	214.8	190.0	237.3	242.4	263.0	239.2	207.4	258.7	48
176.0	170.6	181.6	187.3		192.2	187.1	197.0	210.5		207.5	200.0	217.1	229.7		49
205.1	247.5	199.6	166.8	208.2	242.1	307.7	227.6	187.1	227.3	267.8	342.4	252.4	201.0	258.7	50
175.0	191.4	176.2	167.9	185.8	190.2	207.6	190.0	187.9	194.6	206.2	221.8	206.6	204.9	208.8	51
163.3	166.0	163.0	164.4	160.8	178.0	182.9	177.8	178.0	173.5	191.2	199.0	192.0	188.8	184.1	52
169.7	173.2	167.0	165.5	164.1	179.1	205.3	179.6	179.6	180.1	185.7	183.6	187.2	189.7	189.2	53
allowance (millions of dollars) [5]															
7,050					8,314					9,648					54
4,070					4,401					4,719					55

Table 2.—Business and Government Expenditures for Air and Water Pollution Abatement in Current and Constant Dollars and Selected Implicit Price Deflators

	1972	1973	1974	1975	1976	1977	1978 [r]			1979 [r]			1980 [r]			1981 [p]		
	Total [1]	Total [1]	Total [1]	Total [1]	Total [1]	Total [1]	Total [1]	Air	Water	Total [1]	Air	Water	Total [1]	Air	Water	Total [1]	Air	Water
	Millions of current dollars																	
Business (line 6) [3]	9,111	11,148	13,193	15,751	17,683	19,793	22,287	11,072	11,215	26,136	13,691	12,446	29,853	16,690	13,163	32,474	18,630	13,844
On capital account (line 7)	5,089	6,422	7,016	8,416	9,004	9,581	10,301	5,317	4,984	11,585	6,317	5,268	12,264	7,198	5,066	12,599	7,892	4,707
Motor vehicle emission abatement	225	339	444	770	963	1,158	1,407	1,407		1,819	1,819		2,127	2,127		2,923	2,923	
Plant and equipment expenditures [3]	3,601	4,612	5,297	6,576	6,783	6,840	7,016	3,910	3,106	7,706	4,499	3,207	8,354	5,071	3,283	8,009	4,969	3,040
Residential systems [4]	1,260	1,468	1,268	1,063	1,250	1,575	1,873		1,873	2,057		2,057	1,780		1,780	1,664		1,664
Agricultural business [5]	3	3	7	7	8	8	5		5	4		4	3		3	3		3
On current account (line 8)	4,022	4,726	6,178	7,335	8,679	10,212	11,987	5,755	6,231	14,551	7,373	7,178	17,589	9,492	8,097	19,875	10,738	9,137
Private (line 9)	2,871	3,384	4,545	5,440	6,459	7,610	8,936	5,683	3,253	11,030	7,267	3,763	13,503	9,344	4,159	15,211	10,582	4,629
Motor vehicle emission abatement	435	610	1,060	1,294	1,492	1,659	1,912	1,912		2,640	2,640		3,804	3,804		4,523	4,523	
Manufacturing establishments	1,363	1,509	1,806	2,221	2,754	3,312	3,747	2,037	1,710	4,315	2,337	1,977	4,893	2,709	2,184	5,485	3,045	2,440
Privately owned electric utility establishments	311	396	647	698	719	871	1,044	944	100	1,496	1,382	114	1,910	1,780	130	1,985	1,838	147
Other nonmanufacturing establishments	567	658	801	979	1,224	1,473	1,914	790	1,124	2,238	908	1,330	2,530	1,051	1,479	2,829	1,176	1,653
Residential systems [4]	195	211	229	247	268	292	315		315	337		337	360		360	383		383
Agricultural business [5]	(*)	1	1	2	2	3	4		4	5		5	5		5	6		6
Government enterprise (line 10)	1,151	1,342	1,634	1,895	2,220	2,602	3,051	72	2,978	3,521	106	3,415	4,087	148	3,939	4,664	156	4,508
Publicly owned electric utilities	26	33	62	53	66	69	82	72	10	118	106	12	161	148	13	171	156	15
Public sewer systems [6]	1,124	1,308	1,571	1,842	2,153	2,533	2,967		2,967	3,402		3,402	3,926		3,926	4,492		4,492
Other	(*)	1	1	(*)	1	(*)	1		1	1		1	(*)		(*)	(*)		(*)
Government (line 12)	3,602	4,090	5,039	5,956	6,608	6,701	8,321	283	8,038	9,048	368	8,681	8,984	473	8,511	7,628	500	7,128
Federal (line 13)	131	181	252	358	362	385	406	90	316	450	103	347	370	95	275	338	94	244
Federal excl. highway erosion abatement	126	176	248	353	357	379	400	90	310	442	103	339	362	95	267	330	94	236
Highway erosion abatement	5	5	4	5	5	6	7		7	9		9	8		8	8		8
State and local (line 14)	171	171	189	211	205	189	218	(*)	218	257	(*)	257	293	(*)	293	278	(*)	278
State and local excl. highway erosion abatement	(*)	(*)	(*)	1	1	1	(*)	(*)		(*)	(*)		(*)	(*)		(*)	(*)	
Highway erosion abatement	171	171	189	210	204	188	218		218	257		257	293		293	278		278
Government enterprise fixed capital (line 15)	3,299	3,738	4,598	5,387	6,041	6,128	7,697	193	7,504	8,341	265	8,076	8,321	378	7,943	7,012	406	6,606
Publicly owned electric utilities	31	136	177	164	223	269	329	193	136	367	265	102	468	378	91	474	406	68
Public sewer systems [6]	3,268	3,602	4,421	5,223	5,818	5,859	7,368		7,368	7,975		7,975	7,853		7,853	6,538		6,538
	Millions of constant (1972) dollars																	
Business (line 20) [3]	9,111	10,483	10,368	11,133	11,734	12,143	12,659	6,204	6,455	13,180	6,683	6,497	13,061	6,933	6,129	12,871	7,083	5,789
On capital account (line 29)	5,089	6,105	5,847	6,354	6,433	6,419	6,412	3,384	3,028	6,606	3,705	2,902	6,419	3,848	2,571	6,114	3,946	2,168
Motor vehicle emission abatement	225	338	419	670	787	900	1,008	1,008		1,208	1,208		1,307	1,307		1,693	1,693	
Plant and equipment expenditures [3]	3,601	4,370	4,341	4,871	4,775	4,507	4,304	2,376	1,928	4,306	2,496	1,809	4,252	2,541	1,711	3,678	2,253	1,425
Residential systems [4]	1,260	1,394	1,083	808	866	1,006	1,097		1,097	1,090		1,090	859		859	742		742
Agricultural business [5]	3	3	5	5	5	5	3		3	2		2	1		1	1		1
On current account (line 30)	4,022	4,376	4,520	4,779	5,301	5,723	6,247	2,820	3,428	6,573	2,978	3,596	6,642	3,085	3,558	6,757	3,137	3,620
Private (line 31)	2,871	3,114	3,226	3,449	3,857	4,150	4,543	2,792	1,751	4,794	2,946	1,848	4,812	3,045	1,766	4,883	3,098	1,785
Motor vehicle emission abatement	435	566	790	860	935	975	1,068	1,068		1,116	1,116		1,179	1,179		1,259	1,259	
Manufacturing establishments	1,363	1,400	1,323	1,427	1,643	1,785	1,871	980	892	1,956	1,018	938	1,888	1,006	884	1,892	1,001	891
Privately owned electric utility establishments	311	337	314	324	336	379	417	367	50	470	419	52	525	474	51	500	450	50
Other nonmanufacturing establishments	567	611	592	628	729	794	961	378	583	1,020	393	627	984	389	596	992	389	603
Residential systems [4]	195	200	206	209	213	216	224		224	229		229	234		234	238		238
Agricultural business [5]	(*)	(*)	1	1	2	2	2		2	2		2	2		2	3		3
Government enterprise (line 32)	1,151	1,262	1,295	1,330	1,444	1,573	1,704	28	1,676	1,780	32	1,748	1,831	39	1,791	1,875	39	1,836
Publicly owned electric utilities	26	28	30	25	31	30	34	28	5	37	32	5	45	39	5	44	39	5
Public sewer systems [6]	1,124	1,234	1,264	1,304	1,413	1,542	1,671		1,671	1,742		1,742	1,786		1,786	1,831		1,831
Other	(*)	1	1	(*)	(*)	(*)	(*)		(*)	(*)		(*)	(*)		(*)	(*)		(*)
Government (line 34)	3,602	3,806	4,259	4,745	4,934	4,657	5,262	163	5,099	5,118	192	4,926	4,707	228	4,480	3,693	226	3,467
Federal (line 35)	131	169	209	275	257	252	246	48	198	242	48	194	185	43	142	157	41	116
Federal excl. highway erosion abatement	126	165	206	272	253	248	243	48	196	238	48	190	182	43	139	154	41	113
Highway erosion abatement	5	4	3	3	4	4	3		3	4		4	3		3	3		3
State and local (line 36)	171	155	137	148	143	117	102	(*)	102	115	(*)	115	116	(*)	116	114	(*)	114
State and local excl. highway erosion abatement	(*)	(*)	(*)	(*)	1	1	(*)	(*)		(*)	(*)		(*)	(*)		(*)	(*)	
Highway erosion abatement	171	155	137	148	142	117	102		102	115		115	116		116	114		114
Government enterprise fixed capital (line 37)	3,299	3,482	3,913	4,322	4,534	4,288	4,913	115	4,799	4,761	144	4,617	4,407	185	4,222	3,422	185	3,237
Publicly owned electric utilities	31	129	141	116	182	171	196	115	82	200	144	56	230	185	45	216	185	31
Public sewer systems [6]	3,268	3,353	3,772	4,206	4,352	4,117	4,717		4,717	4,561		4,561	4,176		4,176	3,206		3,206
	Selected implicit price deflators [7]																	
Plant and equipment expenditures (see above, business capital account) [3]	100.0	105.6	122.0	135.0	142.0	151.8	163.0	164.5	161.1	179.0	180.2	177.2	196.5	199.6	191.9	217.7	220.5	213.4
Manufacturing, privately owned electric utilities, and other nonmanufacturing establishments (see above, business current account)	100.0	109.1	145.2	163.9	178.5	191.2	206.4	218.6	192.4	233.5	252.9	211.6	274.7	296.7	247.9	304.4	329.4	274.6
Public sewer systems (see above, business current account) [6]	100.0	106.0	124.3	141.2	152.4	164.2	177.6		177.6	195.3		195.3	219.8		219.8	245.4		245.4
Public sewer systems (see above, government, fixed capital) [6]	100.0	107.4	117.2	124.2	133.7	142.3	156.2		156.2	174.9		174.9	188.0		188.0	204.0		204.0

[r] Revised.

[p] Preliminary.

(*) Less than $500,000.

1. Consists of air and water pollution abatement expenditures only.

2. Line numbers correspond to those in table 1.

3. Consists of manufacturing, private and cooperatively owned electric utilities, and other nonmanufacturing companies.

4. Consists of private septic systems and sewer connections linking household plumbing to street sewers.

5. Feedlot operations only, see footnote 1 on table 1.

6. Public sewer systems consists of treatment plants, collection sewers, interceptor sewers, pumping stations, and dry waste disposal plants.

7. Current-dollar estimates divided by constant-dollar estimates.

The Federal Grants Program for Publicly Owned Wastewater Treatment Works

The description that follows of the Federal program of grants-in-aid for the construction of publicly owned treatment works is to provide background information about a major part of total PAC spending: construction of public sewer systems. These systems accounted for 16½ percent of real PAC spending during 1972-81, and decreases in their construction were major factors in the decreases in total PAC spending in 1980 and 1981.

The Federal Water Pollution Control Act Amendments of 1972 established the existing grants program. Among the provisions, two are of special note: (1) For approved wastewater treatment works projects, the Federal share of the covered construction costs (State and local governments pay all costs not covered, e.g., for sewage collection systems of less than the trunk-line level) was 75 percent and the State and local share, 25 percent; (2) municipalities were required to meet secondary treatment requirements by July 1977. Approval of a project was contingent mainly on conformance of technology to that for medium-to-large scale collection and central processing of wastes, but rationing of available funds was also involved. Secondary treatment of wastewater was generally considered to be biological treatment (e.g., using bacterial action) in contrast to primary treatment, a lower level of treatment that is largely mechanical (e.g., using screening devices). Secondary treatment requirement were set at a stringent level and were described both in terms of percent removal of wastes and quality of effluent. When designing the program, Congress expected that the Federal share of construction costs would remain high until the backlog of needs for construction was eliminated and that substantial progress toward eliminating the backlog could be made in 5 years.

The wastewater treatment works grants program was beset during 1972–81 by difficulties stemming from its design and by external difficulties. These sources of difficulties combined after 1977 to bring an end to steady increases in real grants; grants decreased each year thereafter, except in 1979. Decreases were significant in 1978 and 1981. The difficulties stemming from the program's design gradually became apparent: (1) The preferred—i.e., grant-eligible—pollution abatement technology was high cost relative to alternatives, and operation costs, borne by municipalities alone, were large; (2) secondary treatment requirements were set at a level difficult to attain even with the preferred technology; and (3) although the preferred technology was affordable only in densely populated areas, the treatment requirements were uniform for all areas. The external difficulties were inflation and, later, high interest rates. Inflation accelerated after 1972, escalating construction costs and depleting Federal as well as State and local funds. As a result of difficulties (1) and (2) in combination with inflation, only one-half of major municipal systems met secondary treatment requirements by 1977. As a result of difficulty (3), most other treatment systems did not meet the requirements. The taxpayer resistance to growth in State and local government programs that became increasingly apparent around 1978 augmented concern over the extent to which construction and operation of high-cost treatment systems should continue to be encouraged. Inflation contributed to taxpayer resistance, on the one hand, by raising tax bases and taxes and, on the other, by requiring enlarged bond issues to cover the escalating construction costs. High interest rates made it difficult for State and local governments to finance their costs, which accounted for an average of 56 percent of total sewer systems construction costs in 1978 and 39 percent in 1981. Despite these difficulties, 75 percent of public sewer systems met secondary treatment requirements by 1980.

These difficulties led, in time, to changes in program legislation. Amendments in 1977 mandated investigation of alternatives to the preferred technology. The emphasis was to be on medium-to-large scale collection technology and central processing of wastes rather than septic systems or networks thereof, notwithstanding their advantages. The Federal share of construction costs for alternatives that were innovative was increased as an incentive for their exploration. Amendments in 1977 also extended the deadline for meeting secondary treatment requirements to 1983 and allowed, under specified conditions, increased discharge of wastes into the ocean. The latter change increased the options of municipalities without liberalizing secondary treatment requirements. Amendments in 1981 extended the deadline for meeting secondary treatment requirements to 1988 and liberalized requirements for some locations, allowing oxidation ponds, lagoons, and trickling filters to be used if their use would not adversely affect water quality. These amendments also decreased the Federal share of construction costs to 55 percent beginning in fiscal year 1985. The decrease was meant to cause some shift away from the technology preferred until 1985 and indicated that, although this technology was not being put in place at the rate or to the extent originally envisioned by Congress, it was being put in place where most needed. The decrease was viewed as allowing markets to have an increased influence on technology selection and as reducing Federal involvement in State and local government decisionmaking. The long-term effect of these program changes will probably be annual decreases in grants; a decrease in grant is indicated by available data for 1982. A surge in the mid-1980's is possible if State and local governments rush to take advantage of the remaining years of higher Federal funding.

Although the substantial increases in grants during 1972-77 were the primary stimulus to the increases in spending for construction of public sewer systems, after 1977 factors other than changes in grants—external factors impacting directly on State and local governments—began strongly to influence sewer systems construction. Unless their depressing effect on sewer systems construction is reversed (e.g., by lower interest rates, a strong recovery in housing construction requiring connection to sewer systems, or a resurgence of concern about the impact of residential growth on water quality), these external factors, in combination with the expected decreases in grants, will lead to further decreases in sewer systems construction.

Table 3.—Constant-Dollar Spending by Business and Government for Solid Waste Collection and Disposal and Related Series

	Line	1972	1973	1974	1975	1976	1977	1978 r	1979 r	1980 r	1981 p
		Millions of constant (1972) dollars									
Solid waste collection and disposal by means acceptable to Federal, State, and local authorities	1	3,416	3,429	3,564	3,575	3,816	3,982	4,253	4,434	4,513	4,644
Solid waste management	2	4,680	4,687	4,854	4,897	5,206	5,413	5,769	5,980	6,104	6,281
Pollution abatement	3	887	994	1,162	1,260	1,438	1,619	1,897	2,171	2,356	2,554
Other [1]	4	3,792	3,693	3,693	3,637	3,768	3,794	3,872	3,809	3,748	3,727
		Percent change from preceding year									
Solid waste collection and disposal by means acceptable to Federal, State, and local authorities	5		.4	3.9	.3	6.7	4.4	6.8	4.2	1.8	2.9
Solid waste management	6		.1	3.6	.9	6.3	4.0	6.6	3.6	2.1	2.9
Pollution abatement	7		12.1	16.9	8.4	14.1	12.6	17.2	14.5	8.5	8.4
Other [1]	8		−2.6	0	−1.5	3.6	.7	2.0	−1.6	−1.6	−.6

r Revised.

p Preliminary.

1. Consists of spending for the avoidance of the slowing of production or consumption activity due to the accumulation of solid waste and for other purposes except pollution abatement.

compared with a 13½-percent increase in 1980. Energy prices accounted for much of the deceleration. A fixed-weighted index of energy-purchase components (about 10 percent of total PAC) decelerated from an increase of 28 percent in 1980 to 11 percent in 1981. A PAC fixed-weighted index that excludes these components decelerated much less—from a 10-percent increase in 1980 to a 9½-percent increase in 1981.

The increase in the implicit price deflator slowed to 9 percent from 13 percent in 1980. The implicit price deflator measures the average price of PAC purchases in each year; changes in the deflator reflect changes in prices and shifts in the composition of PAC purchases from year to year. The chain and fixed-weighted price indexes, because the composition of PAC purchases in them is held constant, measure only changes in prices. (The chain index is based on the composition of purchases in each preceding year and the fixed-weighted price index is based on the composition of purchases in a base year, 1972.)

Real PAC spending in 1982.—A continued decrease in spending in 1982, larger in absolute terms than in 1981, is indicated by the limited information available as of early 1983. Public sewer systems construction spending decreased, as indicated by data for the first three quarters. Business PA plant and equipment spending decreased, assuming business spending plans reported in a BEA survey in late 1981 were realized.[2] Motor vehicle emission abatement devices spending decreased, as indicated by only minor additions of devices for model year 1982 and decreased unit sales of vehicles. The sum of these decreases is large. Information for all other categories is sketchy, but there is no indication of a substantial increase.

Revisions in real spending, 1978–80.—The last 3 years of the PAC spending series have been revised. Revisions were upward each year: $0.2 billion in 1978, $0.5 billion in 1979, and $0.3 billion in 1980. The two major components revised were motor vehicle emission abatement devices spending and nonmanufacturing (excluding electric utilities) air and water PA current-account spending. The incorporation of new data on imported light-duty trucks and the reclassification by the Environmental Protection Agency of trucks into light- and heavy-duty weight classes led to upward revisions of abatement device spending (i.e., "personal consumption, durables" plus "business capital, motor vehicle emission abatement" spending) from $0.1 to $0.3 billion in each of the 3 years. The incorporation of information for an additional year led to a higher ratio of nonmanufacturing to manufacturing net capital stocks of PA plant and

Table 5.—Federal Grants-in-Aid to State and Local Governments for

	Line	1972	1973	1974	1975	1976	1977	1978 r				
		Total	Total	Total	Total	Total	Total	Total	Air	Water	Solid waste	Other and unallocated
		Millions of										
Pollution abatement and control	1	923	1,057	2,242	2,870	3,306	4,061	4,180	71	4,012	26	42
Pollution abatement	2	758	916	2,112	2,721	3,109	3,815	3,879	(*)	3,871	7	1
Regulation and monitoring	3	66	76	91	102	151	194	214	68	124	15	12
Research and development	4	99	65	39	47	45	51	87	3	17	4	29
		Millions of constant										
Pollution abatement and control	5	923	983	1,906	2,304	2,546	2,847	2,644	46	2,544	16	28
Pollution abatement	6	758	851	1,794	2,196	2,401	2,679	2,471	(*)	2,455	4	1
Regulation and monitoring	7	66	71	78	79	110	132	136	40	78	9	8
Research and development	8	99	61	34	30	35	37	38	5	11	3	19

r Revised.

p Preliminary.

*Less than $500,000.

1. Constant-dollar estimates are derived using measures of price change of goods and services purchased by State and local governments for pollution abatement and control.

---

[2] For details, see Gary L. Rutledge and Betsy D. O'Connor, "Plant and Equipment Expenditures by Business for Pollution Abatement, 1981 and Planned 1982," SURVEY 62 (June 1982): 17–21 and 72.

Table 4.—Percent Change From Preceding Year in Pollution Abatement and Control Expenditures (Total and Selected Components) in Current and Constant Dollars, Implicit Price Deflators, and Price Indexes

	1972-80 average annual rate[1]	1973	1974	1975	1976	1977	1978[r]	1979[r]	1980[r]	1981[p]
Pollution abatement and control—total:										
Current dollars	14.9	19.0	19.8	17.8	12.2	9.6	14.4	14.9	12.3	7.6
1972 dollars	4.7	11.8	3.4	8.0	5.7	2.0	6.2	2.3	-.8	-1.2
Implicit price deflator	9.6	6.4	15.9	9.0	6.1	7.4	7.7	12.4	13.2	8.9
Chain price index		6.5	15.9	9.8	6.2	7.2	7.7	12.4	13.5	9.4
Fixed-weighted price index	9.9	6.5	15.9	9.8	6.2	7.4	7.9	12.4	13.4	9.5
Pollution abatement and control—air:										
Current dollars	18.7	28.4	25.6	22.9	10.3	10.0	11.2	21.4	21.8	15.2
1972 dollars	7.1	20.8	3.3	12.7	4.7	2.7	3.9	5.5	4.7	7.7
Implicit price deflator	10.8	6.2	21.6	9.1	5.4	7.1	7.0	15.0	16.2	6.9
Chain price index		6.5	21.7	10.8	5.7	7.3	7.1	15.6	17.5	9.4
Fixed-weighted price index	11.7	6.5	22.5	10.9	5.7	7.7	7.0	15.8	18.1	10.1
Business capital—air:										
Current dollars	14.9	27.9	16.7	25.7	-.3	3.8	7.3	18.8	13.9	9.8
1972 dollars	6.2	22.0	1.3	13.6	-4.7	-2.0	.8	9.5	3.9	2.8
Implicit price deflator	8.1	4.8	15.2	10.6	4.7	5.9	6.4	8.5	9.7	6.9
Chain price index		4.5	15.7	11.7	5.2	6.5	7.0	9.1	10.0	9.2
Fixed-weighted price index	8.8	4.5	15.9	11.9	5.2	6.7	6.6	9.4	10.6	10.3
Business current account, private—air:										
Current dollars	23.1	18.2	42.6	20.0	17.6	17.1	15.6	27.9	28.6	13.3
1972 dollars	7.0	7.3	5.4	9.1	11.8	6.7	7.6	5.5	3.4	1.7
Implicit price deflator	15.0	10.1	35.3	10.0	5.2	9.8	7.5	21.2	24.4	11.3
Chain price index		10.2	37.2	10.4	6.6	9.4	7.5	20.7	23.6	11.3
Fixed-weighted price index	14.7	10.2	37.2	10.5	6.5	9.9	8.0	18.4	21.2	11.5
Pollution abatement and control—water:										
Current dollars	12.5	15.6	15.3	16.6	14.4	8.5	18.0	9.7	2.9	-3.1
1972 dollars	2.9	8.4	2.1	6.6	6.6	.4	8.4	-1.0	-6.8	-12.5
Implicit price deflator	9.2	6.7	12.8	9.4	7.2	8.1	9.0	10.8	10.4	10.7
Chain price index		6.7	13.0	9.8	7.0	7.5	8.8	10.5	10.2	9.5
Fixed-weighted price index	9.2	6.7	12.9	9.7	7.2	7.6	9.2	10.4	9.9	9.3
Business capital—water:										
Current dollars	8.0	16.0	1.5	13.2	16.6	9.4	7.7	5.7	-3.8	-7.1
1972 dollars	-.8	9.5	-10.0	2.8	9.1	1.8	-1.1	-4.2	-11.4	-15.7
Implicit price deflator	8.8	5.9	12.7	10.1	6.9	7.4	9.0	10.3	8.5	10.2
Chain price index		6.0	12.7	10.5	6.8	7.1	8.5	10.2	9.0	10.3
Fixed-weighted price index	8.9	6.0	12.8	10.6	7.5	7.4	8.7	10.3	9.0	10.0
Business current account, private—water:										
Current dollars	17.9	17.4	21.0	19.1	20.8	19.1	20.7	15.7	10.5	11.3
1972 dollars	6.0	10.3	.7	3.5	11.9	9.2	12.6	5.5	-4.4	1.0
Implicit price deflator	11.2	6.4	20.1	15.1	8.0	9.1	7.2	9.6	15.6	10.2
Chain price index		6.3	20.2	15.1	7.6	8.8	6.9	9.5	16.0	10.3
Fixed-weighted price index	11.0	6.3	20.0	15.0	7.6	8.8	6.8	9.3	15.5	10.1
Pollution abatement and control—solid waste:										
Current dollars	12.3	8.2	16.8	8.4	11.5	10.3	12.4	16.0	14.6	13.5
1972 dollars	3.7	.8	4.3	.9	6.3	4.2	6.8	4.6	2.3	4.2
Implicit price deflator	8.2	7.3	11.9	7.5	5.0	5.8	6.1	10.9	12.1	8.9
Chain price index		7.3	12.0	7.5	4.9	5.8	6.2	10.8	12.1	9.1
Fixed-weighted price index	8.3	7.3	12.0	7.4	4.9	5.9	6.3	10.8	12.1	9.1

[r] Revised.

[p] Preliminary.

1. Compounded annually; not calculated for chain price index because it is defined for adjacent years only.

Pollution Abatement and Control in Current and Constant Dollars [1]

1979[r]					1980[r]					1981[p]					Line
Total	Air	Water	Solid waste	Other and unallocated	Total	Air	Water	Solid waste	Other and unallocated	Total	Air	Water	Solid waste	Other and unallocated	
current dollars															
5,099	81	4,898	43	77	5,241	85	5,027	53	76	4,836	86	4,593	89	68	1
4,797	(*)	4,784	7	6	4,928	(*)	4,910	9	9	4,532	(*)	4,476	26	30	2
231	73	93	33	32	249	80	94	42	34	276	86	106	59	25	3
71	7	21	3	39	64	5	23	3	33	28	(*)	11	4	13	4
(1972) dollars															
2,914	48	2,794	26	46	2,778	45	2,663	29	41	2,369	43	2,249	45	32	5
2,734	(*)	2,727	4	3	2,608	(*)	2,600	5	4	2,219	(*)	2,193	13	12	6
137	43	55	20	19	134	42	50	23	19	135	42	51	30	13	7
43	5	12	2	24	35	3	13	2	18	15	(*)	6	2	7	8

equipment, which, in turn, led to upward revisions in nonmanufacturing air plus water PA current-account spending of $0.1 billion in each year.

Real spending for air and water PA, 1972–81

Air and water PA, which accounts for most of PAC spending, is discussed in this section using classifications in Federal legislation (tables 6 and 7). For air PA, the Clean Air Act classifies sources of pollutants as mobile (e.g., cars) or stationary (e.g., factories). For water PA, the Federal Water Pollution Control Act classifies sources as point (e.g., factories) or nonpoint (e.g., highway construction projects).

Spending to reduce emissions of air pollutants from mobile and stationary sources combined increased at an average annual rate of 7 percent during 1972–81. Spending for mobile sources increased at an average rate of 14 percent; spending for stationary sources increased at a rate of 1 percent. Spending for emission abatement devices for mobile sources increased much faster than spending to operate the devices, 23½ percent compared with 5 percent (average annual increases).

Spending for air PA facilities for stationary sources was less in 1981 than in 1972. For the subperiod 1972–75, the average annual increase was 4½ percent, but for 1975–81 spending decreased. Annually, spending for facilities was volatile, with increases in 4 years and decreases in 5. Spending to operate these facilities increased steadily from 1975 to 1980 at an annual rate of 7 percent and decreased 1½ percent in 1981.

Water PA spending for point sources increased at an average annual rate of 1½ percent during 1972–81. Spending for water PA facilities for point sources was less in 1981 than in 1972. For 1972–75, the average annual increase was 7½ percent, but for 1975–81 spending decreased. Spending increased every year in the early period, but decreased in 4 out of 6 years in the later period. Spending to operate water PA facilities increased every year except 1980; the average increase for the period was 6 percent. Spending estimates for nonpoint sources are of limited coverage, but indicate that spending decreased at an average annual rate of 6 percent during 1972–81.

Business PAC costs, 1972–81

One possible measure of the costs associated with PAC is the costs of conforming to PAC rules and regulations.[3] For business, such a measure would include, in addition to business current-account PA spending, a capi-

---

[3] Alternatively, business PAC costs are the amount by which business costs exceed what they would have been in the absence of PAC rules and regulations. In both formulations, regulations refer to legal requirements, and rules—written and unwritten—refer to additional expressions of community and business concern for PAC.

Table 6.—Constant-Dollar Spending for Abatement of Air Pollutant Emissions from Mobile and Stationary Sources [1]

[Millions of constant (1972) dollars]

	1972	1973	1974	1975	1976	1977	1978 r	1979 r	1980 r	1981 p
Total	6,290	7,120	7,428	8,514	9,212	9,105	9,435	9,974	10,495	11,402
Mobile sources [2]	2,196	2,959	3,315	4,119	4,879	4,820	5,142	5,425	5,819	7,045
Devices	701	1,098	1,070	1,849	2,576	2,583	2,824	3,151	3,592	4,718
Cars	588	943	865	1,579	1,942	2,236	2,352	2,489	3,105	4,257
Catalytic	0	0	300	917	1,086	1,187	1,204	1,266	1,436	1,590
Noncatalytic	588	943	565	660	856	1,049	1,148	1,223	1,669	2,667
Trucks	113	155	205	270	634	347	472	662	487	461
Operation of devices	1,495	1,861	2,245	2,265	2,303	2,237	2,318	2,274	2,227	2,327
Cars	1,348	1,601	1,886	1,784	1,668	1,475	1,404	1,228	1,049	999
Trucks [3]	147	260	359	481	635	762	913	1,046	1,178	1,328
Stationary sources	4,044	4,161	4,113	4,395	4,333	4,285	4,293	4,549	4,676	4,357
Facilities	2,626	2,864	2,827	2,997	2,741	2,577	2,492	2,640	2,736	2,438
Industrial	2,563	2,786	2,745	2,926	2,608	2,457	2,377	2,495	2,541	2,253
Manufacturing	1,142	1,453	1,586	1,640	1,254	1,095	1,155	1,177	1,086	1,000
Nonmanufacturing	1,421	1,333	1,159	1,286	1,354	1,362	1,222	1,318	1,455	1,253
Other [4]	63	78	82	71	133	120	115	144	195	185
Operation of facilities	1,418	1,297	1,286	1,399	1,592	1,708	1,801	1,909	1,940	1,919
Industrial	1,339	1,228	1,216	1,317	1,496	1,621	1,724	1,829	1,908	1,840
Manufacturing	772	746	686	738	882	942	980	1,018	1,006	1,001
Nonmanufacturing	567	482	530	579	615	679	744	811	902	839
Other [5]	79	69	70	82	96	87	77	80	32	79

r Revised.

p Preliminary.

1. The Clean Air Act classifies sources of pollutants as either mobile, such as passenger cars, or stationary, such as factories.

2. Excludes spending to reduce emissions from mobile sources other than cars and trucks; such spending was insignificant during 1972–81.

3. These estimates are from sources requiring updating; evidence suggesting less spending is accumulating.

4. Consists of spending for fixed capital of government enterprises such as the Tennessee Valley Authority.

5. Consists of spending to operate government enterprises and all spending by government; separate data on spending to acquire and operate government pollution abatement facilities are not available.

Table 7.—Constant-Dollar Spending for Abatement of Water Pollutant Emissions from Point Sources [1]

[Millions of constant (1972) dollars]

	1972	1973	1974	1975	1976	1977	1978 r	1979 r	1980 r	1981 p
Total	7,551	8,214	8,535	9,297	9,916	9,883	10,823	10,641	9,906	8,644
Facilities	5,436	5,831	6,078	6,711	7,098	6,846	7,421	7,132	6,465	5,144
Industrial	1,411	1,585	1,596	1,945	2,137	2,060	1,928	1,809	1,683	1,425
Manufacturing	626	839	852	998	1,173	1,164	801	725	615	495
Nonmanufacturing	785	746	744	947	964	896	1,127	1,084	1,068	930
Public sewer systems, private connectors to them, and other	4,025	4,246	4,482	4,766	4,961	4,786	5,493	5,323	4,782	3,719
Public sewer systems and private connectors	4,003	4,193	4,418	4,717	4,907	4,730	5,409	5,265	4,736	3,687
Other [2]	22	54	64	49	54	56	84	58	46	32
Operation of facilities	2,115	2,384	2,457	2,586	2,818	3,037	3,402	3,509	3,441	3,500
Industrial	912	1,021	1,022	1,062	1,210	1,297	1,525	1,617	1,531	1,544
Manufacturing	591	655	646	671	760	843	892	938	884	891
Nonmanufacturing	321	366	376	391	450	454	633	679	647	653
Public sewer systems, private connectors to them, and other	1,203	1,363	1,435	1,524	1,609	1,740	1,877	1,892	1,910	1,956
Public sewer systems and private connectors	1,124	1,234	1,264	1,304	1,413	1,542	1,671	1,742	1,786	1,831
Other [3]	79	129	171	220	196	198	206	150	124	125

r Revised.

p Preliminary.

1. The Federal Water Pollution Control Act defines point sources as facilities that discharge to a body of water through a pipe or ditch.

2. Consists of spending by owners of feedlots and spending for fixed capital of government enterprises such as the Tennessee Valley Authority.

3. Consists of spending to operate government enterprises and all spending by government; separate data on spending to acquire and operate government pollution abatement facilities are not available.

tal consumption allowance, a net imputed return for PA capital, and research and development spending.[4] Estimates of business PAC costs have been prepared for 1972–81 (table 8).[5] Business PAC costs in current dollars increased at an average annual rate of 17¼ percent during 1972–81. The two major components, "costs of PAC-induced modifications in final products" and "costs of business PAC of its own wastes," increased at average rates of 20¼ percent and 16¾ percent, respectively. The addition of emission abatement devices to motor vehicles is an example of the former kind of costs, and the use of electricity to operate the wastewater treatment works of a manufacturing operation is an example of the latter.

What is generated by business PAC costs, although not a final demand in the framework of the national income and product accounts (NIPA's), has characteristics of a final demand: the clean air and water they generate are products, albeit unconventional ones, for consumption, and are not inputs to further production. Further, business PAC costs, although not a tax, have characteristics of a tax: (1) they are not used to benefit the businesses directly affected, but rather to purchase resources used for collective consumption, and (2) the costs may be shifted forward or backward as markets allow. For some types of analysis, users of the NIPA's may want to consider the provision of clean air and water as collective consumption and the tax characteristics of business PAC costs. Doing so may improve the internal logic of the study and suggest useful interpretations of results. To date, resource absorption has been considered systematically only for those cost components classified as final demand in the NIPA's; specifically, economic growth models have excluded PA capital but not labor and materials. The tax characteristics of business PAC costs as a whole have not been considered, although two aspects have been: business PA as affecting relative prices, and business PA capital as reducing the rate of return.

Table 8.—Business Pollution Abatement and Control (PAC) Costs in Current Dollars [1]

[Millions of dollars]

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Business PAC costs	12,807	15,019	16,876	20,885	25,609	30,803	35,909	40,845	46,005	53,880
Costs of PAC-induced modifications in final products	2,023	2,551	2,492	3,386	4,385	5,346	6,404	7,542	8,562	10,945
Residential systems [2]	1,260	1,468	1,268	1,063	1,250	1,576	1,873	2,057	1,780	1,664
Motor vehicles [3]	701	1,009	1,150	2,225	3,012	3,634	4,375	5,306	6,561	8,993
Adjustment to market price valuation [4]	62	74	73	98	123	137	156	179	221	288
Costs of business PAC of its own wastes [5]	10,784	12,468	14,384	17,499	21,224	25,457	29,505	33,303	37,443	42,935
Residential business	4,519	4,700	4,488	5,361	6,153	7,180	7,913	8,058	8,006	8,966
Current costs	196	211	229	247	269	292	315	337	360	343
Capital costs [6]	4,091	4,239	4,040	4,747	5,578	6,542	7,227	7,346	7,242	8,104
Capital consumption allowance	540	582	673	766	812	906	1,046	1,179	1,308	1,441
Net imputed return [7]	2,841	2,960	2,606	3,117	3,762	4,610	5,214	5,190	4,946	5,614
Adjustment to a market price valuation [4]	232	250	219	367	306	345	371	374	404	479
Nonfarm nonresidential business	6,265	7,768	9,896	12,138	15,071	18,277	21,592	25,246	29,437	33,967
Current costs	2,780	3,341	4,817	5,679	6,790	7,990	9,507	11,870	14,725	16,717
Motor vehicles	436	610	1,060	1,294	1,492	1,669	1,912	2,640	3,994	4,523
Air and water pollution abatement, except motor vehicles	2,620	3,013	3,799	4,512	5,386	6,441	7,665	9,190	10,656	11,757
Solid waste pollution abatement	162	188	496	566	799	846	1,005	1,400	1,685	2,224
Costs recovered	−438	−470	−538	−693	−887	−966	−1,075	−1,360	−1,610	−1,787
Capital costs [6]	3,042	3,942	4,508	5,846	7,450	9,319	10,999	12,144	13,321	15,640
Capital consumption allowance	989	1,264	1,728	2,278	2,804	3,398	4,009	4,885	5,862	7,018
Motor vehicles	46	70	107	168	250	360	450	644	852	1,101
Air and water pollution abatement, except motor vehicles	934	1,180	1,597	2,074	2,506	2,972	3,470	4,118	4,847	5,708
Solid waste pollution abatement	8	14	24	37	48	66	89	123	163	209
Net imputed return [7]	1,611	2,080	2,081	2,739	3,568	4,670	5,569	5,765	5,789	6,810
Motor vehicles	55	50	56	91	146	219	298	333	361	482
Air and water pollution abatement, except motor vehicles	1,546	2,013	2,002	2,613	3,373	4,380	5,175	5,322	5,304	6,168
Solid waste pollution abatement	10	17	22	35	49	71	96	110	124	160
Research and development for pollution abatement	154	192	225	161	281	364	376	435	416	414
Adjustment to a market price valuation [4]	289	293	346	452	541	604	710	798	975	1,196
Addendum:										
Net imputed return adjustment [8]										
Residential business	381	487	1,201	1,384	1,146	722	665	1,404	2,357	2,342
Nonfarm nonresidential business	216	342	1,111	1,216	1,085	731	699	1,558	2,759	2,841

1. Derived from tables 1 and 2, detail underlying these tables, related national income and product account data, and capital stocks for pollution abatement. Information on sources and methods used in these estimates will be provided upon request.

2. Consists of the construction of private septic systems and sewer connections linking household plumbing to street sewers.

3. Consists of motor vehicle emission abatement systems and the added consumer expense of purchasing unleaded rather than leaded fuel.

4. Consists of sales-associated charges: part of indirect business taxes (those contingent upon sale), business transfer payments (made out of sales revenue), and the statistical discrepancy. These charges are measured as what they would have been if resources used for pollution abatement had been used to produce final product. Business PAC costs are adjusted to market prices to make them comparable to other values at market prices.

5. Consists of the costs of a business' abatement of its own waste (self service), one business' abatement of another business' waste, and related research and development.

6. Includes items not shown separately, insurance and taxes on pollution abatement capital.

7. Consists of the pollution abatement net capital stock multiplied by the ratio of nonlabor earnings to assets for nonfarm corporate business and measures what businesses would have earned if capital used for pollution abatement had been used to produce final product.

8. The amount shown may be added to the net imputed return when a trended rather than an untrended earnings-to-assets ratio is required.

---

[4] Net imputed return is what businesses would have earned if capital used for PA had been used for purposes other than PA (i.e., what businesses forego when they use capital for PA); it is estimated as the PA net capital stock multiplied by the ratio of nonlabor earnings to assets for nonfarm corporate business.

[5] Information on sources and methods used in these estimates will be provided upon request. Send requests to U.S. Department of Commerce, Bureau of Economic Analysis, BE-62, Washington, D.C. 20230.

By WILLIAM J. RUSSO, JR. and GARY L. RUTLEDGE

Plant and Equipment Expenditures by Business for Pollution Abatement, 1982 and Planned 1983

U.S. NONFARM business spent $8.5 billion in 1982 for new plant and equipment to abate air and water pollution and to dispose of solid waste, down from $8.9 billion in 1981 (table 1).[1] These estimates are based on a survey conducted in November and December 1982 by BEA. The 4.9-percent decrease in 1982 followed a 2.9-percent decrease in 1981 (chart 6). Plans indicate that spending in 1983 will decrease 2.7 percent to $8.3 billion.

Preliminary estimates indicate that prices, as measured by the implicit price deflator for pollution abatement (PA) plant and equipment, increased 6.7 percent in 1982, compared with a revised 10.6-percent increase in 1981 (table 2).[2] The 1982 increase was the smallest since 1976. Based on information available in mid-1983, prices are likely to increase less in 1983 than in 1982; assuming price increases in the range of 2 to 5 percent, real PA plant and equipment spending will decrease 4.7 to 7.2 percent in 1983.

Real spending for PA plant and equipment decreased 11.0 percent in 1982, compared with a 12.1-percent decrease in 1981. Decreases for air, water, and solid waste PA were 12.9 percent, 6.3 percent, and 15.0 percent, respectively. After reaching a peak of $5.2 billion in 1975, real spending for PA plant and equipment decreased each year, except for 1979.

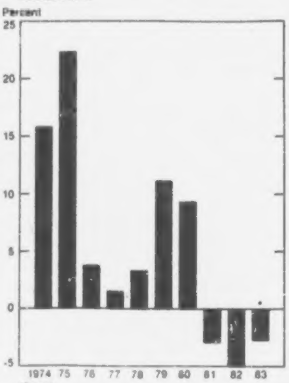
Spending patterns

Air and water pollution abatement is achieved by either end-of-line methods or by changes-in-production-process methods. End-of-line methods treat pollutants after they are generated; changes-in-production-process methods are preventive, reducing the generation of pollutants and the need for treatment. End-of-line spending accounted for over three-fourths of air and water PA plant and equipment spending in 1982. This spending responds faster to changes in environmental-regulatory conditions and more general economic conditions affecting investment than changes-in-production-process spending, which often must await completion of research and development on specific processes. Spending on both methods increased steadily until 1980. End-of-line spending decreased in 1981 and 1982 while changes-in-production-process spending increased (table 3).

Spending for air PA plant and equipment decreased 5.6 percent (to $4.7 billion) in 1982, the largest decrease since the series began. This decrease followed a 2.0-percent decrease in 1981. The only other decreases occurred in 1976 (5.2 percent) and 1977 (0.3 percent). Business plans indicate a further decrease of 13.4 percent this year. After adjustment for price change, spending for air PA plant and equipment decreased 12.9 percent in 1982, to a level one-third below its 1975 peak.

CHART 6

Percent Change in New Plant and Equipment Expenditures for Pollution Abatement



[1] Planned

U.S. Department of Commerce, Bureau of Economic Analysis 8364

---

[1] Pollution abatement (PA) is the reduction or elimination of emissions of pollutants that is brought about by human activity directed to that purpose. Disposal of solid waste refers to the collection and disposal of solid waste by means acceptable to Federal, State, and local authorities. Part of expenditures for disposal of solid waste is not for PA, but presenting only the PA portion is not feasible at the level of detail in this article. For further discussion of pollution abatement and solid waste disposal, see John E. Cremeans, "Conceptual and Statistical Issues in Developing Environmental Measures—Recent U.S. Experience," *Review of Income and Wealth*, ser. 23 (June 1977): 97-115, and Gary L. Rutledge and Susan L. Trevathan, "Pollution Abatement and Control Expenditures, 1972-79," SURVEY OF CURRENT BUSINESS 61 (March 1981): 19-27.

The survey results are universe estimates for U.S. nonfarm business of PA plant and equipment expenditures, excluding expenditures for emission abatement devices on cars and trucks. The estimates are based on sample data from companies, each of which is assigned to a single industry corresponding to the industry classification of the company's principal product. For a brief description of survey methodology, see Technical Note 1 in Gary L. Rutledge and Betsy D. O'Connor, "Plant and Equipment Expenditures by Business for Pollution Abatement, 1973-80, and Planned 1981," SURVEY 6[illegible] 1981): 19-25, 30, and 72.

Expenditures by business for emission abatement devices on cars and trucks were $2.9 billion in 1981. For earlier estimates of these expenditures, see Gary L. Rutledge and Susan L. Trevathan, "Pollution Abatement and Control Expenditures, 1972-81," SURVEY 63 (February 1983): 15-23.

[2] Price indexes generally applicable to (although not specific to) PA plant and equipment are used to derive the implicit price deflator. The implicit price deflator for 1982 is based on preliminary estimates for these indexes. Year-to-year changes in the PA implicit price deflators reflect changes in prices and in the composition of pollution abatement capital. Past changes have primarily reflected price changes; shifts in composition have had little effect.

Table 1.—New Plant and Equipment Expenditures by U.S. Nonfarm Business: Total and for Pollution Abatement

[Billions of dollars]

	1981					1982					Planned 1983				
	Total ¹	Pollution abatement				Total ¹	Pollution abatement				Total ¹	Pollution abatement			
		Total	Air	Water	Solid waste		Total	Air	Water	Solid waste		Total	Air	Water	Solid waste
Total nonfarm business	321.49	8.93	4.97	3.04	0.92	316.43	8.49	4.69	2.98	0.82	310.92	8.36	4.06	3.34	0.86
Manufacturing	126.79	5.42	2.69	2.10	.63	119.68	4.72	2.25	1.94	.51	115.90	4.63	1.83	2.25	.56
Durable goods	61.84	1.97	1.09	.70	.18	56.44	1.76	.88	.69	.14	54.22	1.63	.80	.66	.16
Primary metals ²	8.12	.78	.54	.19	.06	7.46	.76	.45	.27	.03	5.96	.58	.32	.22	.04
Blast furnaces, steel works	3.17	.49	.33	.13	.02	3.47	.41	.21	.19	.01	2.56	.26	.13	.12	.01
Nonferrous metals	3.46	.23	.15	.05	.03	2.71	.30	.20	.08	.02	2.38	.28	.17	.10	.02
Fabricated metals	2.96	.07	.02	.04	(*)	2.50	.04	.02	.02	(*)	2.34	.03	.01	.01	(*)
Electrical machinery	10.31	.18	.08	.07	.02	10.62	.15	.06	.08	.02	[illegible]	.14	.05	.08	.01
Machinery, except electrical	13.22	.15	.06	.08	.01	12.80	.18	.08	.08	.03	[illegible]	.20	.08	.08	.03
Transportation equipment ²	18.29	.44	.20	.21	.08	15.16	.40	.21	.16	.03	14.[illegible]	.43	.22	.22	.06
Motor vehicles	10.08	.36	.16	.16	.04	7.92	.33	.18	.12	.02	8.06	.39	.19	.18	.02
Aircraft	6.43	.10	.03	.06	.02	6.04	.06	.03	.04	.01	5.55	.09	.03	.04	.02
Stone, clay, and glass	3.14	.16	.12	.03	.01	2.61	.08	.06	.01	.02	2.43	.09	.06	.02	.01
Other durables ³	5.09	.16	.07	.07	.02	5.13	.15	.07	.07	.02	4.84	.12	.05	.06	.01
Nondurable goods	64.95	3.46	1.60	1.40	.45	63.23	2.96	1.36	1.25	.36	61.60	3.00	1.03	1.57	.40
Food including beverage	8.22	.30	.13	.14	.04	7.74	.38	.17	.16	.04	7.46	.33	.14	.15	.04
Textiles	1.56	.05	.03	.02	(*)	1.33	.08	.01	.06	(*)	1.31	.08	.01	.06	(*)
Paper	6.72	.38	.16	.12	.11	5.97	.30	.15	.06	.09	6.00	.43	.17	.16	.09
Chemicals	13.69	.86	.36	.36	.14	13.27	.67	.22	.27	.17	13.60	.64	.21	.36	.06
Petroleum	26.56	1.76	.88	.74	.14	26.00	1.50	.67	.67	.16	24.57	1.59	.46	.95	.18
Rubber	1.77	.04	.02	.02	.01	1.71	.04	.02	.01	.01	1.84	.03	.01	.01	.01
Other nondurables ⁴	6.53	.04	.02	.01	.01	6.52	.04	.02	.01	.01	6.71	.05	.03	.03	.01
Nonmanufacturing	194.70	3.51	2.28	.94	.29	196.75	3.77	2.41	1.04	.32	195.02	3.63	2.23	1.10	.30
Mining	16.86	.46	.18	.18	.10	15.45	.52	.21	.20	.11	15.45	.63	.30	.26	.06
Transportation	12.05	.09	.04	.04	.01	11.[illegible]	.14	.06	.06	.01	11.[illegible]	.12	.06	.06	.01
Railroad	4.24	.04	.02	.02	(*)	4.[illegible]	.06	.05	.03	(*)	4.21	.08	.04	.03	.01
Air	3.81	.01	.01	(*)	(*)	3.38	.01	.01	.00	(*)	3.32	(*)	(*)	.00	(*)
Other	4.00	.05	.02	.02	(*)	3.84	.05	.03	.02	.01	3.46	.04	.01	.02	(*)
Public utilities	36.40	2.90	1.98	.87	.15	41.96	3.00	2.07	.77	.15	41.[illegible]	2.76	1.83	.76	.17
Electric	29.74	2.71	1.91	.65	.15	33.40	2.89	2.01	.73	.15	33.[illegible]	2.65	1.76	.72	.17
Gas and other	6.[illegible]	.09	.06	[illegible]	(*)	8.52	.11	.06	.06	.01	7.[illegible]	.11	.07	.04	(*)
Trade and services	96.[illegible]	.11	.06	.04	.03	86.95	[illegible]	.04	.02	.03	87.78	.09	.03	.02	.04
Communication and other ⁵	41.96	.08	.02	.01	(*)	40.48	[illegible]	.01	.01	(*)	39.78	.02	.01	(*)	(*)

*Less than $5 million.

1. Consists of final estimates taken from the quarterly surveys of total new plant and equipment and, for 1983, plans based on the survey taken in late January and February 1983.

2. Includes industries not shown separately.

3. Consists of lumber, furniture, instruments, and miscellaneous.

4. Consists of apparel, tobacco, leather, and printing-publishing.

5. Consists of communication; construction; social services and membership organizations; and forestry, fisheries, and agricultural services.

Although business planned to increase water PA plant and equipment spending 12.8 percent for 1982, actual spending decreased 2.0 percent. Business again plans a substantial increase (12.1 percent) for 1983. After adjustment for price change, spending for water PA plant and equipment decreased 12.9 percent in 1982; it too is about one-third below its 1976 peak. Real spending has decreased each year since 1976.

Business spending for solid waste disposal plant and equipment decreased 10.9 percent in 1982, after increasing substantially each year since 1975. Plans indicate an increase of 4.9 percent in 1983. After adjustment for price change, spending for solid waste disposal plant and equipment decreased 15.0 percent in 1982. Despite the decrease, real spending in 1982 was above that in 1975.

In 1982, business allocated 2.7 percent of total plant and equipment spending to PA, compared with 2.8 percent in 1981. If business spending for motor vehicle emission abatement devices is added to PA plant and equipment spending, the allocation is 3.6 percent in 1982 and 3.7 percent in 1981.

Industry detail.—Manufacturing industries decreased spending for PA plant and equipment 12.9 percent in 1982 and plan a further decrease of 1.9 percent in 1983 (table 4). They accounted for 55.6 percent of total PA plant and equipment spending in

Table 2.—New Plant and Equipment Expenditures for Pollution Abatement in Current and Constant Dollars with Implicit Price Deflators

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
	Billions of dollars									
Total	4.92	5.70	6.97	7.33	7.34	7.60	8.42	9.30	8.93	8.49
Air	2.92	3.37	4.02	3.81	3.80	3.91	4.50	5.07	4.97	4.69
Water	1.69	1.93	2.56	2.97	3.04	3.11	3.21	3.38	3.04	2.98
Solid waste	.31	.40	.39	.46	.50	.58	.71	.85	.92	.82
	Billions of constant (1972) dollars									
Total	4.67	4.68	5.16	5.09	4.83	4.64	4.69	4.64	4.08	¹3.66
Air	2.79	2.74	2.93	2.64	2.45	2.38	2.50	2.54	2.25	1.96
Water	1.59	1.60	1.96	2.14	2.05	1.90	1.81	1.70	1.42	1.26
Solid waste	.30	.34	.29	.32	.33	.33	.36	.41	.40	.34
	Implicit price deflators, 1972=100									
Total	105.5	121.8	135.0	142.6	151.8	163.3	179.6	196.1	219.0	¹232.7
Air	105.0	122.6	137.4	144.5	154.6	164.5	180.2	199.6	220.6	238.7
Water	106.5	121.0	131.4	139.0	148.4	161.1	177.2	193.4	213.5	223.7
Solid waste	104.3	118.8	134.4	141.6	152.9	168.0	196.2	208.7	229.8	243.7

1. The implicit price deflators for 1982 are based on preliminary source data.

Table 3.—New Plant and Equipment Expenditures by U.S. Nonfarm Business for Air and Water Pollution Abatement by End-of-Line Methods [1]

[Billion of dollars]

	1981			1982			Planned 1983		
	Total	Air	Water	Total	Air	Water	Total	Air	Water
Total nonfarm business	6.40	4.03	2.37	5.86	3.58	2.28	5.68	3.12	2.56
Manufacturing	3.85	2.17	1.68	3.13	1.59	1.54	3.09	1.33	1.76
Durable goods	1.35	.83	.51	1.21	.65	.56	1.15	.59	.56
Primary metals [2]	.62	.46	.16	.59	.35	.24	.45	.26	.19
Blast furnaces, steel works	.44	.31	.13	.36	.17	.19	.22	.11	.11
Nonferrous metals	.14	.11	.03	.21	.15	.06	.21	.13	.08
Fabricated metals	.04	.01	.03	.02	.01	.01	.02	.01	.01
Electrical machinery	.11	.06	.04	.11	.04	.06	.10	.04	.06
Machinery, except electrical	.11	.03	.08	.13	.06	.07	.12	.05	.08
Transportation equipment [2]	.23	.11	.12	.23	.12	.11	.31	.14	.16
Motor vehicles	.18	.09	.09	.19	.11	.08	.27	.13	.14
Aircraft	.05	.02	.03	.03	.01	.02	.04	.02	.02
Stone, clay, and glass	.12	.10	.02	.05	.04	.01	.05	.04	.01
Other durables [3]	.11	.06	.05	.09	.04	.05	.10	.05	.06
Nondurable goods	2.50	1.34	1.17	1.91	.93	.99	1.94	.74	1.20
Food including beverage	.18	.10	.08	.15	.08	.07	.12	.05	.07
Textiles	.03	.01	.02	.03	.01	.02	.02	.01	.01
Paper	.15	.09	.07	.16	.10	.06	.18	.11	.07
Chemicals	.69	.36	.33	.49	.26	.23	.38	.17	.21
Petroleum	1.40	.77	.63	1.03	.45	.58	1.18	.38	.80
Rubber	.03	.01	.02	.02	.01	.01	.02	.01	.01
Other nondurables [4]	.03	.02	.01	.02	.01	.01	.03	.01	.02
Nonmanufacturing	2.55	1.86	.69	2.73	1.99	.74	2.59	1.80	.80
Mining	.34	.17	.17	.38	.20	.17	.51	.28	.23
Transportation	.07	.04	.03	.11	.07	.04	.10	.05	.05
Railroad	.03	.01	.02	.07	.04	.03	.07	.04	.03
Air	(*)	(*)	.00	(*)	(*)	.00	(*)	(*)	.00
Other	.04	.02	.02	.03	.02	.01	.03	.01	.02
Public utilities	2.06	1.61	.45	2.20	1.70	.50	1.94	1.44	.50
Electric	2.01	1.58	.44	2.15	1.68	.47	1.88	1.41	.47
Gas and other	.05	.03	.02	.05	.02	.03	.07	.04	.03
Trade and services	.06	.03	.03	.04	.02	.02	.03	.01	.02
Communication and other [5]	.02	.02	(*)	.01	.01	(*)	.01	.01	(*)

*Less than $5 million.

1. End-of-line methods involve the separation, treatment, or reuse of pollutants after they are generated but before they are emitted from a company's property. Changes-in-production-process estimates for air and water pollution abatement can be derived by subtracting estimates in this table from those in table 1.

2. Includes industries not shown separately.

3. Consists of lumber, furniture, instruments, and miscellaneous.

4. Consists of apparel, tobacco, leather, and printing-publishing.

5. Consists of communication; construction; social services and membership organizations; and forestry, fisheries, and agricultural services.

1982, down from 60.7 percent in 1981 and from a high of 70.7 percent in 1975. Plans indicate a slight increase to 56.1 percent in 1983. If plans are realized, the water share of manufacturing PA plant and equipment will exceed that for air for the second time and the solid waste share will reach its highest level since the series began in 1973.

Durable goods industries decreased spending for PA plant and equipment 10.7 percent in 1982 and plan a further decrease of 7.4 percent in 1983. They accounted for 20.7 percent of total PA plant and equipment spending in 1982, down from a high of 29.7 in 1973. Nondurable goods industries decreased spending 14.5 percent in 1982 and plan an increase of 1.4 percent in 1983. They accounted for 34.9 percent of total PA plant and equipment spending in 1982, down from a high of 43.5 percent in 1975.

Nonmanufacturing industries increased spending 7.4 percent in 1982 and plan a decrease of 3.7 percent in 1983. Their share of total PA plant and equipment spending increased to 44.4 percent in 1982.

Of the major spenders, industries reporting decreases for 1982 were chemicals (23.9 percent), paper (21.1 percent), blast furnaces (16.3 percent), and petroleum (14.8 percent). Industries reporting increases were nonferrous metals (30.4 percent) and electric utilities (6.6 percent). Except for paper and electric utilities, these spending patterns in 1982 were due more to environmental-regulatory conditions than to more general economic conditions affecting investment.[3] The six industries accounted for over 70 percent of cumulative PA plant and equipment spending from 1973 to 1982.

Table 4.—New Plant and Equipment Expenditures for Pollution Abatement: Percent Change From Preceding Year

	1981	1982	Planned 1983
Total nonfarm business	−2.9	−4.9	−2.7
Manufacturing	−1.8	−12.9	−1.9
Durable goods	−12.2	−10.7	−7.4
Nondurable goods	8.8	−14.5	1.4
Nonmanufacturing	−4.9	7.4	−3.7
Electric utilities	−3.9	6.6	−8.2
Other nonmanufacturing	−8.0	10.0	11.4

---

[3] This statement assumes that changes in environmental-regulatory conditions are indicated by changes in the proportion of plant and equipment spending allocated to pollution abatement.

Current Industrial Reports

Issued January 1983

Pollution Abatement Costs and Expenditures, 1981

MA-200(81)-1

U.S. Department of Commerce
Malcolm Baldrige, Secretary
Guy W. Fiske, Deputy Secretary
Robert G. Dederick, Under
Secretary for Economic Affairs

BUREAU OF THE CENSUS
Bruce Chapman,
Director

Introduction

SUMMARY OF SURVEY RESULTS

Pollution abatement capital expenditures by manufacturing establishments with 20 employees or more amounted to $3,485 million in 1981. Of this total, $2,194 million was for air pollution abatement, $1,028 million was for water pollution, and $263 million was for solid waste pollution abatement. In addition, operating costs related to pollution abatement activities (including payments to governmental units) totaled $9,110 million in 1981 of which $3,698 million was spent for air pollution, $3,554 million for water pollution, and $1,856 million for solid waste pollution. These totals for 1981 compare with $3,503 million in capital expenditures and $8,142 million in operating costs for 1980. Although the overall decline in total pollution abatement capital expenditures was 1 percent, air and solid waste capital expenditures both registered a 4 percent increase. Water pollution capital expenditures decreased $119 million or 11 percent in 1981. All components of pollution abatement operating costs (air, water, and solid waste) registered increases as in the previous year. Total operating costs increased $968 million or 12 percent.

Data in this publication are collected in the annual census report, Survey on Pollution Abatement Costs and Expenditures, (Form MA-200). See appendix A for a reproduction of the report form and instructions.

POLLUTION ABATEMENT CAPITAL EXPENDITURES

Approximately 68 percent of the $3,485 million new capital expenditures for pollution abatement were made by establishments classified in four major industry groups. In order of value, they include Chemicals and Allied Products (major group 28), Primary Metal Industries (major group 33), Petroleum and Coal Products (major group 29) and Paper and Allied Products (major group 26). These same industries also accounted for the largest amount of pollution abatement capital expenditures in previous years. Chart A illustrates this concentration, on a historical basis, for air, water, and solid waste capital expenditures by major industry group.

In 1981, the States of Texas, Pennsylvania, California, and Michigan accounted for about 33 percent of the total new pollution abatement capital expenditures. Chart B illustrates the pollution capital expenditures by State. Chart C shows the total capital expenditures for pollution abatement for the 10 largest standard metropolitan statistical areas (SMSA) ranked by number of manufacturing employees in 1978. (Appendix B contains the definitions for each SMSA.)

Within tables 2A, 2B, and 2C both air and water pollution abatement capital expenditures are separated on the basis of abatement technique, distinguishing between plant and equipment designed to abate pollutants through end-of-line (EOL) techniques and those designed to reduce or eliminate the generation of pollutants through changes-in-production processes (CIPP). These data show that the major portion of pollution abatement capital expenditures is spent on EOL techniques.

Separate expenditure data are also shown in these tables for major types of air pollutants to be abated such as particulates; sulfur oxides; nitrogen oxides, hydrocarbons, and carbon monoxides; and heavy metals, radioactive and toxic substances, and other. These data show that the largest share of capital expenditures for air pollution abatement in 1981, as in earlier years, related to particulates. (Where expenditures occur for techniques that abate both sulfur oxides and particulates, the respondent was instructed to include all such expenditures with sulfur oxides.)

Pollution abatement capital expenditures reported in this survey exclude expenditures for the reduction of noise pollution and the improvement of aesthetics or employees comfort or safety. Also excluded are purchase of motor vehicles with pollution abatement devices and expenditures to assure an adequate water supply for production. Manufacturers of pollution abatement equipment of materials, such as electrostatic precipitators or desulfurized fuels, to be sold to others for pollution abatement purposes were instructed to exclude expenses associated with the development and production of these products.

POLLUTION ABATEMENT OPERATING COSTS

Operating costs related to pollution abatement totaled $9,110 million in 1981. The operating costs (excluding payments to governmental units) totaled $8,423 million for plants with 20 or more employees and consisted of $1,487 million for depreciation, $1,796 million for labor, $2,568 million for materials and supplies, and $2,569 million for services, equipment leasing, and other costs. Chart D shows the relationship between capital expenditures and operating costs by form of pollutant being abated for 1981. Chart E shows pollution abatement operating costs by type of expense for 1981.

Certain industries typically rely more on governmental units for pollution abatement activities rather than utilizing capital investments and operations at their own plant. Those industries with the largest amounts are Food and Kindred Products

CHART A.

Capital Expenditures by Manufacturers for Pollution Abatement–
By Form of Abatement and Major Industry Group: 1977 to 1981

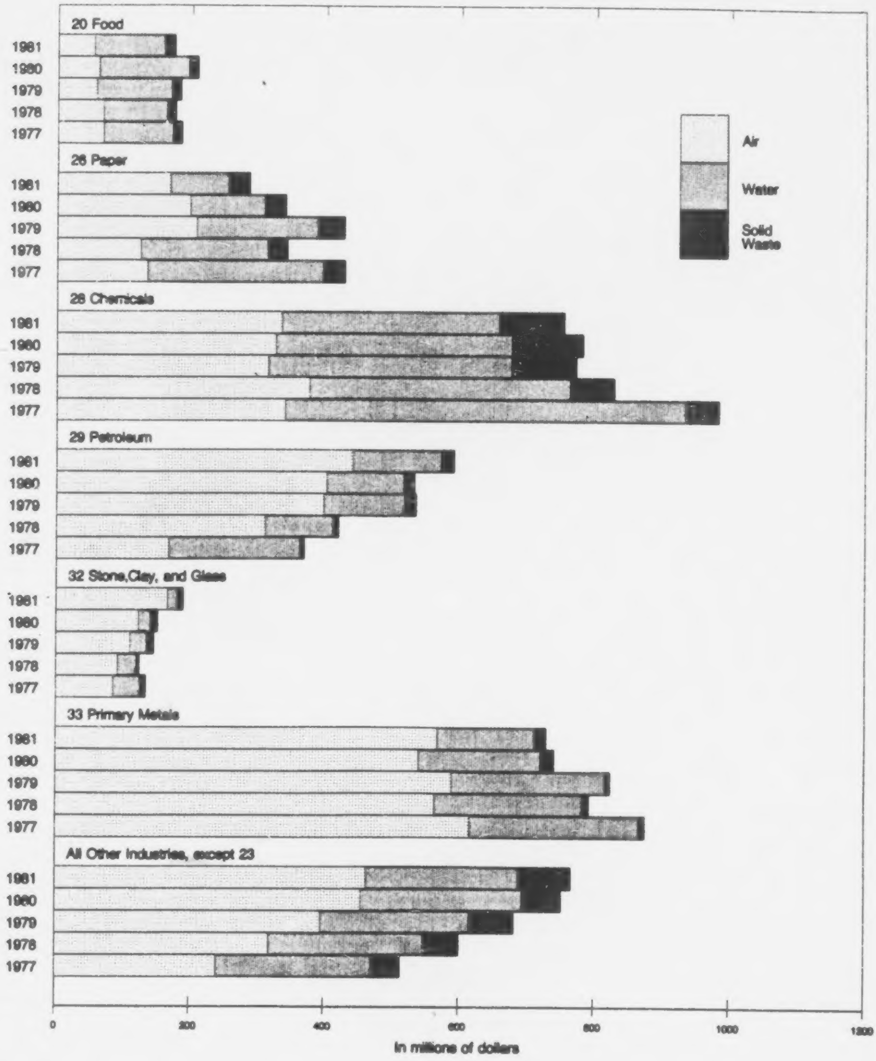


CHART B.

Capital Expenditures by Manufacturers for Pollution Abatement- By State: 1981

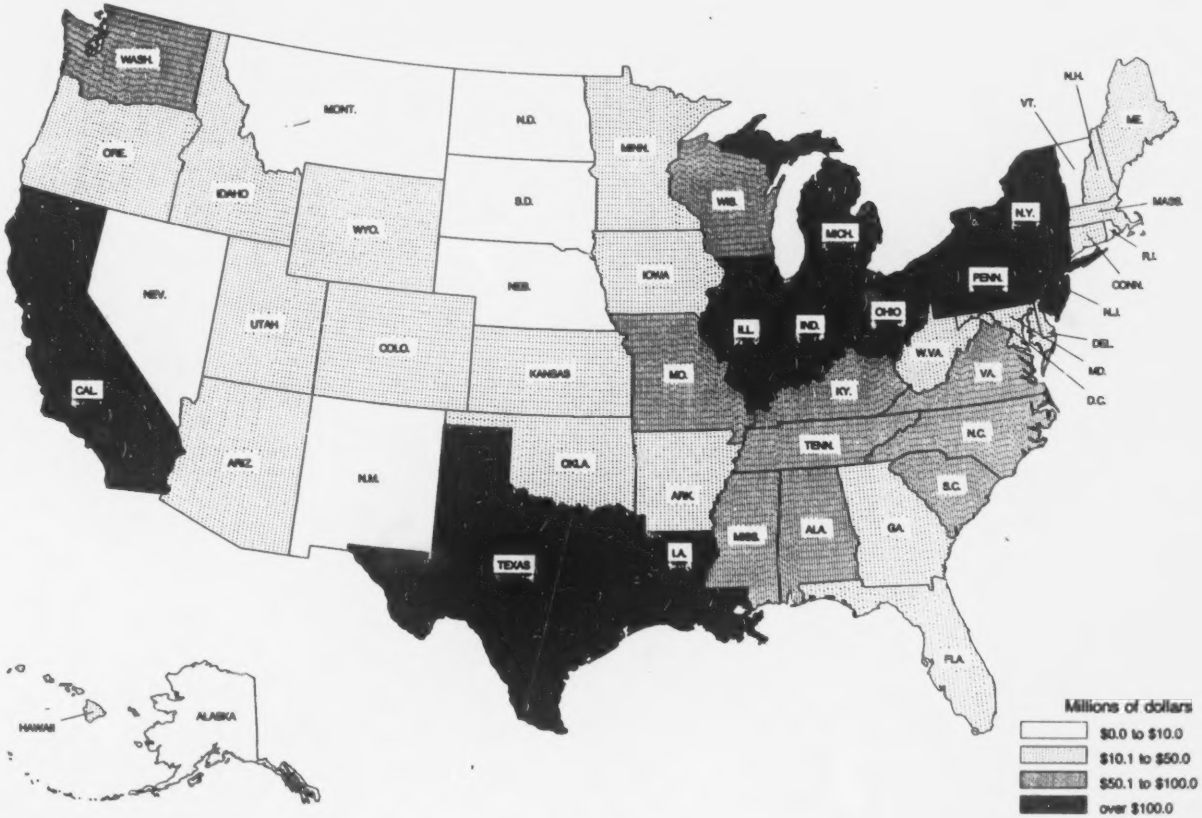

WASH.
ORE.
CAL.
NEV.
IDAHO
MONT.
WYO.
UTAH
ARIZ.
COLO.
N.M.
N.D.
S.D.
NEB.
KANSAS
OKLA.
TEXAS
MINN.
IOWA
MO.
ARK.
LA.
WIS.
ILL.
MICH.
IND.
OHIO
KY.
TENN.
MISS.
ALA.
GA.
FLA.
S.C.
N.C.
VA.
W.VA.
PENN.
N.Y.
VT.
N.H.
ME.
MASS.
R.I.
CONN.
N.J.
DEL.
MD.
D.C.
HAWAII
ALASKA
Millions of dollars
$0.0 to $10.0
$10.1 to $50.0
$50.1 to $100.0
over $100.0

CHART C.

Capital Expenditures by Manufacturers for Pollution Abatement–
By Standard Metropolitan Statistical Areas With the Largest
Manufacturing Employment, Ranked by Number of Employees: 1981

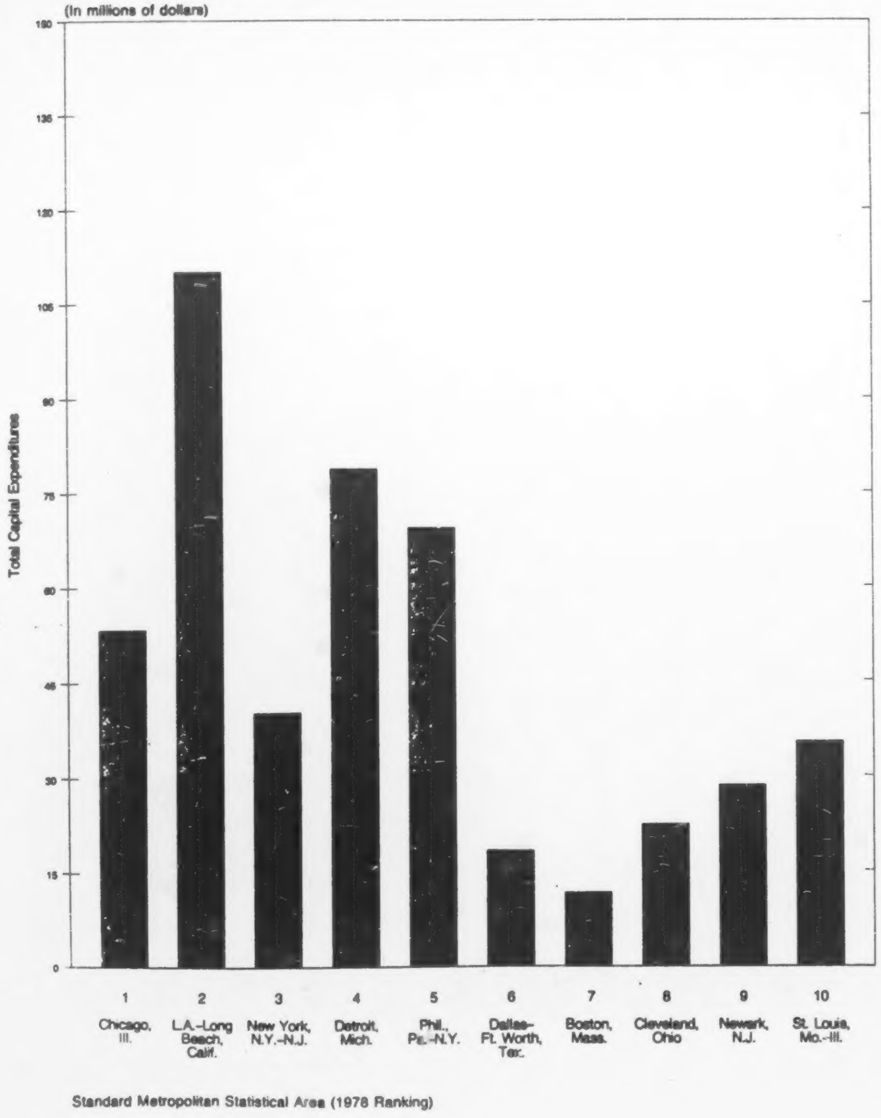


CHART D.

Capital Expenditures and Annual Operating Costs by Manufacturers for Pollution Abatement–
By Form of Abatement and Major Industry Group: 1981

(In millions of dollars)

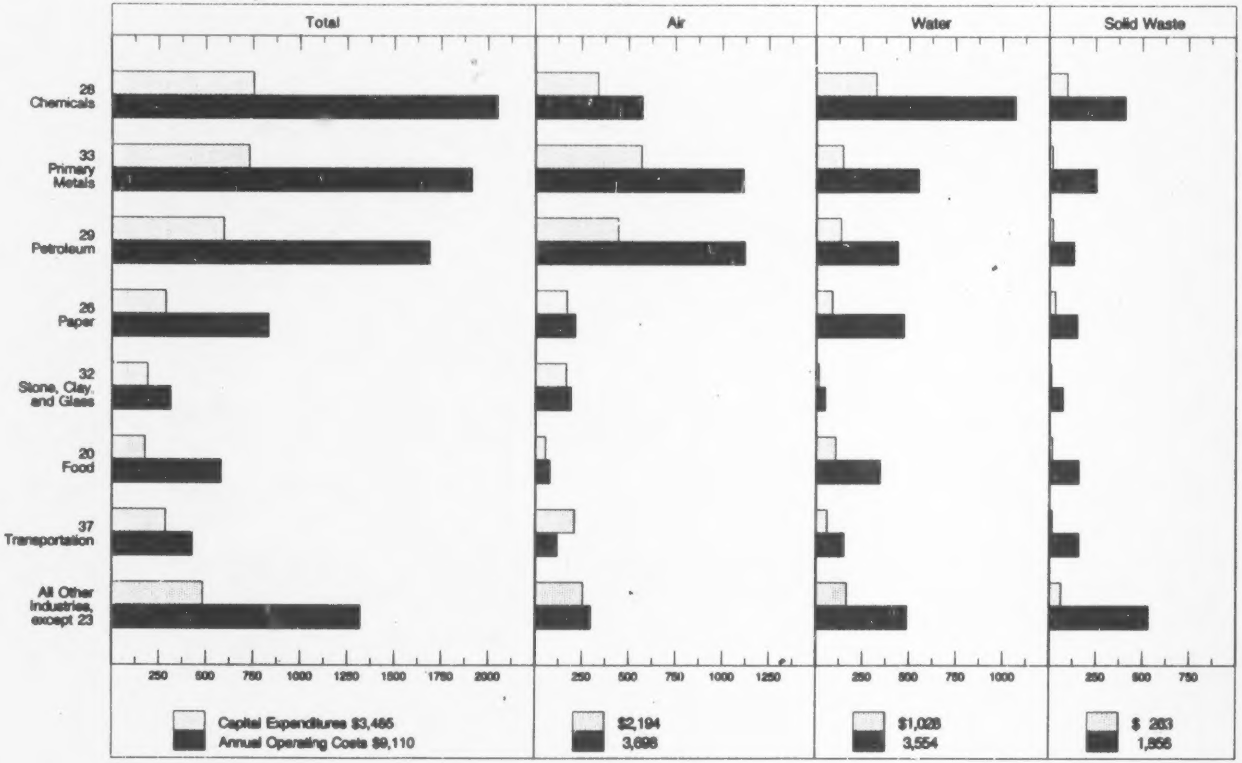
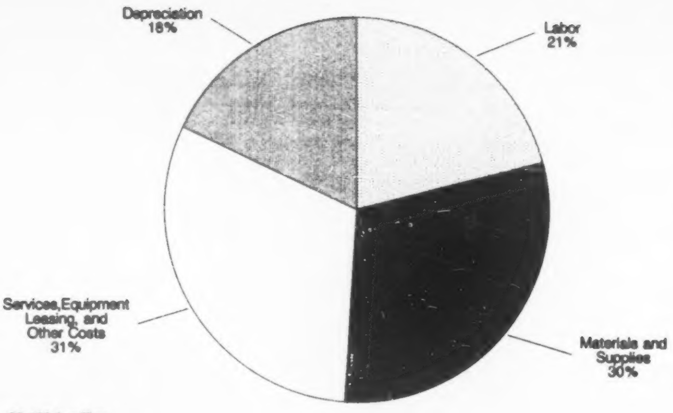


CHART E.

Operating Costs by Manufacturers for Pollution Abatement–
By Type of Expense for
All Industries: 1981



Note: Total operating costs, $8,422.6 million
(excluding payments to governmental units)

(major group 20), Chemicals and Allied Products (major group 28), and Paper and Allied Products (major group 26). (For another Census Bureau report on the pollution abatement activities in the public sector, see *Environmental Quality Control, Government Finances: Fiscal Year 1980.)*

OTHER INFORMATION IN TABLES

In addition to the data on capital expenditures and operating costs, there are a number of tables which present other information of importance. Tables 4A, 4B, and 4C contain information on the costs recovered by manufacturers either by reuse in production or by sale. Tables 5A, 5B, and 5C present data on quantities of air, water, and solid waste pollutants removed in 1981.

For an explanation of the terms used in this report, see appendix A, which is a reproduction of the report form and instructions.

ABBREVIATIONS

The following abbreviations and symbols appear frequently in the tables:

*	Less than $0.5 million.
(NA)	Not available.
r	Revised from previously published figures.
–	Represents zero.
(D)	Withheld to avoid disclosing operations of individual companies.
p	Preliminary.
(S)	Data suppressed because did not meet publication standards. This includes cells where PACE or GAC is less than $5.0 million or the standard error is 20 or greater. See text.
(X)	Not applicable.
(Z)	Represents less than $50,000.
TNCE	Total New Capital Expenditures.
BEA	Bureau of Economic Analysis
PACE	Pollution Abatement Capital Expenditures
GAC	Pollution Abatement Gross Annual Costs

DESCRIPTION OF THE SURVEY SAMPLE

The statistics presented in this report are estimates compiled from a survey of a probability sample of about 20,000 manufacturing establishments with 20 employees or more selected as a subsample of the 1977 Annual Survey of Manufactures (ASM). The 1977 ASM was in turn, a probabilty sample of about 70,000 establishments selected from a total of about 312,000 establishments. The ASM sample was selected from the 1972 Census of Manufactures lists supplemented by Social Security Administration lists of new manufactures that opened after 1972. At that time, the ASM sample was defined on a company rather than an establishment basis; that is, selected companies were required to report for all of their plants in the ASM so that new establishments of existing companies were included in the ASM sample.

The following specific differences between the 1977 ASM sample and the pollution abatement expenditures (PAE) sample are worthy of note:

1. Establishments in major group 23, Apparel and Other Textile Products, are excluded from the PAE survey. These establishments operate primarily in rented quarters where the abatement of pollution (probably most of which is solid waste) is generally arranged by the landlord. We assume that capital expenditures for pollution abatement in such establishments are minimal.

2. The PAE sample was selected as an establishment sample rather than a company sample; that is, a company included in the ASM sample with 10 manufacturing plants might be included in the PAE survey for only 4 of the plants.

3. The 1977 to 1981 PAE sample does not include any establishments with fewer than 20 employees. This is a departure from previous PAE (and the present ASM) panels which included establishments of all sizes. Previous PAE surveys had indicated that establishments with fewer than 20 employees contributed only about 2 percent to the pollution estimates while constituting more than 10 percent of the sample size. To reduce the reporting burden for small establishments, plants with fewer than 20 employees were eliminated from the 1977 sampling frame. In previous reports, data for establishments with fewer than 20 employees had been estimated and displayed in tables 1A and 1B. This series has been discontinued and will not appear in future reports.

The probabilities of selection assigned to establishments in the sampling frame (all in-scope ASM establishments) were determined so that the final probabilities of selection of the PAE sample were proportional to the establishments' value of shipments in the 1976 ASM. Out of a total fixed sample size of 20,000 plants, all establishments with a value of shipments in the 1976 ASM of $30.1 million or more were included in the PAE survey. Establishments in the 1977 ASM sample with less than $30.1 million value of shipments in 1976 were assigned probabilities of selection ranging from 0.99 to 0.005.

The smaller establishments were arrayed by industry and selected systematically to assure a proportionate representation from each major industry group. Establishments chosen for the PAE survey were assigned weights equal to the reciprocal of the establishment's probabilty of selection. Individual establishment data were inflated by their sampling weights to develop industry, State, or SMSA estimates.

LIMITATIONS OF DATA

Conceptual Problems

Changes-in-production processes (CIPP) **capital expenditures.** The survey respondent is instructed to report "the difference between expenditures on new plant and equipment that your establishment actually made for changes-in-production processes and what your establishment would have spent for comparable plant and equipment without pollution abatement features." Telephone conversations and interviews with survey respondents indicate that estimating such an incremental cost difference is very difficult in may instances. The net effect of this reporting problem is not known and hence, care should be exercised by the data user in interpreting the CIPP data.

Cost recovered through abatement activities. This question attempts to measure how much of pollution abatement costs are recovered through reuse or sale. Part of the instructions state: "Exclude the value of salable items such as scrap if the sale represents essentially an economic rather than pollution decision." This qualification makes it imperative that the data preparer be aware of the original motivation of the decision in order to adequately complete the form. The Bureau of the Census believes this is not always known.

Operating cost for pollution abatement. The survey respondent is asked to provide separately depreciation, labor, materials and supplies, services and equipment leasing, and other costs. In many cases, interviews with survey respondents have revealed that with the exception of depreciation, book records are not kept for each category and must be estimated from other information.

Sampling Variation

The particular sample selected for this survey is one of a large number of similar probability samples of the same size that could have been selected, by chance, using the same sample design. Each of the possible samples would yield somewhat different sets of results. The sampling errors—the differences between the estimate obtained and the results theoretically obtainable from a comparable complete canvass of the same target universe—are unknown. Guides to the potential size of the sampling errors, however, are provided by the estimated relative standard errors of the estimates. These are shown for a few key data items in the report. On the average, relative standard errors tend to be somewhat higher for detailed figures than for larger aggregates.

In conjunction with its associated estimates, the relative standard error (computed as the estimated standard error of estimate divided by the value of the estimate itself) may be used to define confidence intervals, ranges which could be expected to include comparable complete coverage values for specified percentages of all possible samples. The complete coverage value would be included in the range:

1. From one standard error below to one standard error above the derived estimate for about two-thirds of all samples.

2. From 2 standard errors below to 2 standard errors above the derived estimate for about 19 out of 20 of all possible samples.

3. From three standard errors below to three standard errors above the derived estimate for nearly all samples.

An inference that the comparable complete coverage results would be within the indicated ranges would be correct in approximately the relative frequencies shown. Those proportions, therefore, may be interpreted as defining the confidence that the estimates shown would differ from complete-coverage results by as much as one, two, or three standard errors, respectively.

For example, if an estimated total is shown as $20.0 million with an associated relative standard error of 2 percent, the standard error is $0.4 million (2 percent of $20.0 million). Then there is approximately 67 percent confidence that the interval $19.6 to $20.4 million includes the complete coverage total, about 95 percent confidence that the interval $19.2 to $20.8 million includes the complete coverage total, and almost certain confidence that the interval $18.8 to $21.2 million includes the complete coverage total.

Processing Errors

In addition to the sampling errors, the estimates are subject to various response and operational errors: errors of collection, reporting, transcription, etc. These operational errors would also occur if a complete canvass were to be conducted under the same conditions as this survey. Explicit measures of their effects generally are not available. However, it is believed that most of the important operational errors were detected and corrected in the course of the Census Bureau's review of the data for reasonableness and consistency.

COMPARISON OF BUREAU OF ECONOMIC ANALYSIS AND CENSUS DATA

The Bureau of the Census estimates of total capital expenditures and pollution abatement expenditures are generally lower than those published by the Bureau of Economic Analysis (BEA) in the Survey of Current Business. Since both sets of data are based on samples, some of the differences by industry are to be expected. However, most of the differences result from the types of reporting units used to collect the data.

The Census Bureau survey relies on the establishment as the reporting unit. The census questionnaire covers only capital expenditures at the particular location engaged in manufacturing selected for the sample. In aggregating the data, the industry group classification is based on the manufacturing activity at that location.

The BEA survey relies on the company as the reporting unit. Each company files a report for its entire operation and that report is classified by industry according to the primary or largest activity of the company as a whole. Companies classified by BEA as primarily manufacturing include many other activities individually classified as retailing, mining, transportation, and services. Reports for such companies cover capital expenditures at establishments in these activities as well as the manufacturing locations.

In this respect, the BEA information for manufacturing tends to be overstated compared to the Census Bureau's. On the other hand, some manufacturing activity takes place in companies which are primarily engaged in retail, service, transportation, or some other nonmanufacturing activity. The capital expenditures applicable to manufacturing activity of these companies are not included in the BEA data for manufacturing but are identified as separate operations in the Census Bureau survey. In this situation, the Census Bureau figures would tend to be higher than the Bureau of Economic Analysis figures.

Because the nonmanufacturing activity of manufacturing companies tends to exceed considerably the manufacturing activity of nonmanufacturing companies, the net effect is to attribute greater capital expenditures to manufacturing in company-based data than in establishment-based data. Over the years, total capital expenditures for manufacturing estimated in census establishment surveys has varied between 60 and 70 percent of the BEA estimates. Table A shows a comparison of BEA and Census total and pollution abatement capital expenditures for 1979 to 1981.

SELECTED INDUSTRIAL AIR POLLUTION CONTROL EQUIPMENT

Table B highlights annual manufacturing data for air pollution control equipment from 1977 to 1981. This information is collected and published in series MA35J, *Selected Industrial Air Pollution Control Equipment*, by the Bureau of the Census. Data in this survey are collected for two types of manufactured air pollution equipment: particulate emissions collectors (e.g., electrostatic precipitators, wet scrubbers) and gaseous emission control devices (e.g., catalytic oxidation systems, gas absorbers). The published report is divided into two parts. The first presents data on quantity and value of new orders, shipments, and backlog of orders at the year-end. The second provides value of the equipment shipped by end use. As shown in the table, steam electric power plants are the largest end user of industrial air pollution control equipment (approximately 47 percent in 1981). In 1981, shipments increased for several manufacturers' end users.

RESEARCH AND DEVELOPMENT FOR POLLUTION ABATEMENT PURPOSES

Tables C and D show the amounts spent from 1977 to 1981, on research and development (R&D) for the purpose of pollution control. These data are collected by the Bureau of the Census and published by the National Science Foundation. Total expenditures for industrial pollution abatement R&D by source of funds, type of pollution abatement, and some detail industry data are not available due to high rates of nonresponse.

REVISION TO 1980 DATA

The data for quantities of solid waste removed in tables 5A, 5B, and 5C of the 1980 report, Pollution Abatement Costs and Expenditures, 1980 MA200(80)-1, issued in December 1980, should be revised as shown in the following partial table:

Quantities of Pollutants Removed and Related Statistics for Establishments With 20 or More Employees: 1980

(Quantities in thousands of short tons)

SIC code	Industry, State and major industry group, or SMSA	Quantity of solid waste removed
	TABLE 5A: INDUSTRY	
	All industries[1]	*149,872.8
33	Primary metal industries	*37,523.9
331	Blast furnace, basic steel products	*21,952.8
3312	Blast furnaces and steel mills	*21,165.3
3313	Electrometallurgical products	466.0
3315	Steel wire and related products	117.3
3316	Cold finishing of steel shapes	186.8
332	Iron and steel foundries	7,674.7
3321	Gray iron foundries	6,172.1
3325	Steel foundries, n.e.c.	1,130.2
333	Primary nonferrous metals	*6,707.5
3331	Primary copper	*5,861.8
3332	Primary lead	106.3
3333	Primary zinc	101.0
3334	Primary aluminum	544.1
3339	Primary nonferrous metals, n.e.c.	94.3
	TABLE 5B: STATE AND MAJOR INDUSTRY GROUP	
	United States[1]	*149,872.8
	Indiana	*10,569.5
20	Food and kindred products	134.5
28	Chemicals and allied products	352.5
29	Petroleum and coal products	(D)
30	Rubber, misc. plastics products	122.8
33	Primary metal industries	*8,155.8
35	Machinery, except electrical	102.7
36	Electric, electronic equipment	133.3
37	Transportation equipment	398.0
	Texas	*15,086.4
26	Paper and allied products	402.8
28	Chemicals and allied products	5,871.8
29	Petroleum and coal products	2,032.8
32	Stone, clay, glass products	1,014.1
33	Primary metal industries	*2,669.2
35	Machinery, except electrical	98.1
36	Electric, electronic equipment	24.8
37	Transportation equipment	101.4
	TABLE 5C: SMSA	
	Gary-Hammond-East Chicago, Ind.	*7,893.5

*Only those data with an asterisk have been corrected.

[1] Major industry group 23, Apparel and Other Textile Products, is excluded.

Table A. Total New Capital Expenditures and Pollution Abatement Expenditures for New Plant and Equipment—BEA and Census, by Industry Group: 1979 to 1981

(In millions of dollars)

Industry group	Data source	1981 TNCE	1981 Pollution abatement expenditures: Total	Air	Water	Solid waste	1980 TNCE	1980 Pollution abatement expenditures: Total	Air	Water	Solid waste	1979 TNCE	1979 Pollution abatement expenditures: Total	Air	Water	Solid waste
All manufacturing	BEA	126,790	5,420	2,690	2,100	630	115,810	5,320	2,880	2,090	350	96,680	4,820	2,250	1,840	730
	Census	(NA)	3,485	2,194	1,028	263	70,569	3,503	2,106	1,147	251	61,537	3,565	2,072	1,246	247
Durable goods	BEA	61,840	1,970	1,090	700	180	58,910	2,270	1,420	690	150	51,070	2,000	1,210	650	140
	Census	(NA)	1,387	1,141	158	88	39,608	1,530	1,062	390	77	33,926	1,551	1,040	440	71
Primary metals	BEA	8,130	780	560	190	30	7,710	980	680	260	40	6,760	920	640	260	20
	Census	(NA)	728	567	144	17	5,498	740	540	181	20	5,129	821	589	227	7
Electrical machinery	BEA	10,310	180	80	70	20	9,590	160	70	60	20	7,280	110	50	60	10
	Census	(NA)	97	49	41	7	7,934	79	44	27	8	6,566	91	42	42	7
Machinery except electrical	BEA	11,720	130	30	90	10	11,190	150	70	70	10	10,520	140	70	60	10
	Census	(NA)	67	31	28	8	8,162	75	34	35	6	9,817	85	39	38	8
Transportation equipment	BEA	18,190	460	200	210	40	18,160	520	310	170	40	11,320	410	190	160	60
	Census	(NA)	283	209	60	14	8,002	275	201	61	13	6,854	190	120	60	10
Stone, clay, and glass	BEA	1,140	160	120	30	10	1,820	250	210	30	10	1,960	210	170	30	10
	Census	(NA)	189	166	14	4	3,039	151	123	18	10	2,506	147	110	25	10
Fabricated metals[2]	BEA	2,960	70	20	40	(Z)	2,960	70	20	30	10	7,270	220	110	90	10
	Census	(NA)	75	37	30	8	3,419	77	18	[illegible]	9	7,981	217	140	48	29
Other durable[2]	BEA	5,690	160	70	70	20	5,590	140	75	60	10					
	Census	(NA)	147	82	41	21	5,036	133	82	34	16					
Nondurable goods	BEA	64,950	3,450	1,600	1,400	450	56,900	3,260	1,460	1,400	400	47,610	2,820	1,343	1,190	290
	Census[1]	(NA)	1,900	1,052	672	177	30,961	1,976	1,044	760	173	27,607	2,014	1,035	806	177
Food, including beverages	BEA	8,220	300	140	140	20	7,390	250	80	160	20	6,620	270	80	160	30
	Census	(NA)	174	56	105	13	7,832	208	62	137	14	6,034	183	58	111	14
Textiles	BEA	1,360	50	30	20	(*)	1,420	70	30	20	(*)	1,500	60	30	20	(*)
	Census	(NA)	48	27	18	3	1,491	40	13	24	4	1,329	38	22	13	2
Paper	BEA	5,720	480	160	120	[illegible]	4,800	290	160	160	70	5,150	400	180	180	50
	Census	(NA)	286	168	87	31	4,213	340	197	111	31	4,667	429	207	181	39
Chemicals	BEA	13,600	880	380	360	140	12,600	730	320	320	100	10,780	630	290	280	60
	Census	(NA)	573	335	172	66	9,743	583	326	330	123	7,976	771	314	361	96
Petroleum	BEA	26,350	1,760	880	740	140	20,630	1,710	830	690	190	16,210	1,280	720	430	130
	Census	(NA)	791	641	132	18	5,541	432	202	116	113	3,273	534	398	119	17
Rubber	BEA	1,770	40	20	10	10	1,730	40	20	10	10	2,170	60	40	10	10
	Census	(NA)	28	17	5	7	2,387	22	13	7	2	2,200	25	13	9	3
Other nondurables	BEA	5,130	40	20	20	10	6,180	40	10	20	10	4,180	40	10	10	20
	Census	(NA)	29	13	9		1,436	37	11	18	4	3,340	36	22	8	6

Note: See text for explanation of differences between BEA and Census estimates.
Totals may not agree with detail because of independent rounding. Census data for pollution abatement expenditures includes only those manufacturing establishments with 20 or more employees; see text.

[1] Major industry group 23, Apparel and Other Textile Products, is excluded from all figures except for TNCE from the Annual Survey of Manufactures.
[2] Appears separately for the first time in this report.

Source: U.S. Bureau of the Census, Survey of Pollution Abatement Cost and Expenditures, 1979-1981; Annual Survey of Manufactures 1979-1980; and the U.S. Bureau of Economic Analysis, Plant and Equipment Expenditures by Business for Pollution Abatement 1973-1981 and Planned 1982, Survey of Current Business, June 1982.

Table B. Selected Industrial Air Pollution Control Equipment: 1977 to 1981

(Millions of dollars)

Air pollution control equipment		Value			Shipments by end use											
		New order	Total shipments	Backlog of orders	Pulp and paper mill operations	Chemical and fertilizer production	Petroleum refining	Cement manufacturing	Foundries	Iron and steel mills	Primary metals smelting plants	Grain milling and handling	Coal mining and cleaning	Steam electric utility power plants	Steam industrial power plants	Other end use industries
Total air pollution control equipment[1]	1981	1,074.0	951.2	1,522.0	32.7	59.1	28.5	20.5	16.0	52.3	36.0	9.4	6.4	461.6	53.8	173.0
	1980	1,159.1	827.3	1,398.4	29.4	61.0	16.4	31.8	16.0	31.1	20.6	6.0	7.1	407.9	59.8	138.1
	1979	710.6	738.4	988.1	31.8	54.0	14.1	19.1	11.1	33.1	16.8	7.0	7.9	376.6	45.5	116.4
	1978	741.5	612.0	916.2	^{r}27.5	41.9	^{r}12.4	^{r}15.9	^{r}11.6	39.4	^{r}5.2	^{r}9.2	6.8	287.0	^{r}38.0	115.3
	1977	605.9	617.1	788.1	28.8	35.3	^{r}12.3	18.3	6.7	^{r}35.7	13.9	^{r}3.8	^{r}6.0	^{r}307.2	^{r}26.4	^{r}122.9
Particulates emission collectors	1981	639.3	691.4	696.2	31.8	34.0	(D)	(D)	15.5	48.9	35.7	9.4	5.7	290.3	41.0	135.8
	1980	582.4	637.4	750.3	28.3	39.6	14.3	(D)	(D)	32.7	20.1	6.0	6.0	(D)	47.9	106.9
	1979	467.1	570.8	742.5	30.4	37.2	(D)	(D)	(D)	32.3	16.5	(D)	5.8	(D)	40.7	96.3
	1978	544.6	497.0	684.9	^{r}25.8	^{r}29.7	(D)	(D)	(D)	35.4	(D)	(D)	(D)	(D)	(D)	^{r}92.7
	1977	460.1	484.1	^{r}650.7	27.6	^{r}20.5	3.4	(D)	(D)	31.4	13.0	(D)	(D)	246.2	^{r}13.3	^{r}96.9
Gaseous emission control devices	1981	417.7	242.1	819.1	(D)	24.5	6.6	-	(D)	(D)	(D)	-	(D)	167.1	9.5	29.5
	1980	552.1	166.4	642.7	(D)	(D)	(D)	(D)	-	(D)	(D)	-	(D)	(D)	(D)	21.5
	1979	209.8	167.3	236.7	(D)	(D)	1.8	-	(D)	(D)	(D)	-	-	(D)	4.3	14.9
	1978	158.3	81.1	199.8	^{r}0.6	(D)	^{r}2.3	-	(D)	0.6	(D)	-	-	(D)	2.7	12.1
	1977	113.0	^{r}94.3	116.4	(D)	(D)	(D)	(D)	(D)	(D)	(D)	-	-	^{r}53.5	^{r}9.1	^{r}13.1

[1] Includes other types of industrial air pollution control equipment not shown separately.

Source: Current Industrial Reports, Selected Industrial Air Pollution Control Equipment, (MA-35J), 1977 to 1981.

Table C. Industrial Research and Development Expenditures for Pollution Abatement, by Type: 1977 to 1981

(Millions of dollars)

Type of pollution abatement	1981^{p}			1980			1979			1978			1977		
	Total	Federal	Company	Total	Federal	Company	Total	Federal	Company	Total	Federal	Company	Total	Federal	Company
Total	(1)	132	(1)	1,183	117	1,066	1,237	98	1,139	1,067	75	992	901	56	845
Air	(1)	(2)	(1)	(2)	(2)	(2)	954	30	923	(2)	(2)	(2)	676	22	654
Water	110	8	102	(2)	(2)	(2)	120	13	107	(2)	(2)	(2)	97	7	90
Solid waste	101	82	19	(2)	(2)	(2)	43	33	11	(2)	(2)	(2)	28	7	21
All other	71	(2)	(2)	(2)	(2)	(2)	120	22	98	(2)	(2)	(2)	100	20	80

[1] Data not available due to high rate of nonresponse.
[2] Not separately available but included in total.

Source: National Science Foundation Bureau of the Census, Survey of Industrial Research and Development, 1977 to 1981.

Table D. Total Industrial Research and Development Expenditures for Pollution Abatement, by Source of Funds and Industry: 1977 to 1981

(Millions of dollars)

Source of funds and industry	1981^{p}	1980	1979	1978	1977
Total	(1)	1,183	1,237	1,067	901
Source of funds:					
Federal funds	132	117	98	75	56
Company funds	(1)	1,066	1,139	992	845
Industry:					
Electrical equipment	40	39	33	19	20
Petroleum refining	92	98	82	72	61
Aircraft and missiles	51	18	64	64	57
Chemical and allied products	196	184	149	81	83
Motor vehicles and equipment	(2)	(2)	(2)	605	487
Other manufacturing	(2)	4	109	107	100
Nonmanufacturing	110	101	111	119	93

[1] Data not available due to high rate of nonresponse.
[2] Not separately available but included in total.

Source: National Science Foundation Bureau of the Census, Survey of Industrial Research and Development, 1977 to 1981.

Table 1A. Pollution Abatement Capital Expenditures and Operating Costs, by Form of Abatement and Major Industry Group: 1977 to 1981

(In millions of dollars, except percents)

SIC code	Industry		Annual Survey of Manufactures (ASM)[1]		Pollution abatement capital expenditures (PACE)				Pollution abatement gross annual costs (GAC) including payments to government units				Percent change (prior year to current year)		Standard error of estimates (percent)	
			Total value of shipments	Total new capital expenditures	Total	Air	Water	Solid waste	Total	Air	Water	Solid waste	PACE	GAC	PACE	GAC
	All industries[2]	1981	(NA)	(NA)	3,484.9	2,193.6	1,028.4	263.1	9,109.9	3,697.8	3,556.3	1,855.7	-1	12	1	1
		1980	1,850,927.0	70,568.8	3,502.9	2,105.5	1,146.5	251.0	8,141.8	3,297.8	3,193.1	1,650.6	-2	10	3	1
		1979	1,727,214.6	61,533.0	3,564.5	2,071.9	1,245.7	266.9	7,399.9	3,061.8	3,015.6	1,322.5	9	18	1	1
		1978	1,522,937.3	^{r}55,209.2	3,279.3	1,853.6	1,266.5	178.9	6,275.7	2,527.4	2,529.9	1,218.2	-6	16	1	2
		1977	1,358,526.4	47,459.0	3,483.5	1,652.0	1,674.1	157.7	5,425.0	2,240.4	2,203.4	981.5	-1	20	1	1
20	Food and kindred products	1981	(NA)	(NA)	173.5	53.9	106.8	14.8	579.1	78.3	343.3	157.5	-17	11	3	2
		1980	255,871.5	5,852.3	208.2	61.7	133.0	13.5	519.6	81.6	314.3	123.6	14	3	4	7
		1979	235,974.7	5,034.2	182.7	57.9	111.1	13.6	504.2	91.0	297.9	115.3	4	22	5	6
		1978	^{r}216,071.2	^{r}4,807.1	175.0	67.7	94.4	12.9	412.0	69.4	243.2	99.4	-5	15	5	4
		1977	192,911.6	4,214.9	183.9	67.9	103.6	12.5	357.1	56.2	211.6	89.5	-11	3	4	3
21	Tobacco products	1981	(NA)	(NA)	(D)	(D)	(D)	(D)	(S)	(S)	(S)	(S)	(X)	(X)	(X)	(X)
		1980	11,892.8	367.3	(D)	(D)	(D)	(D)	14.8	6.8	4.4	3.5	(X)	3	(X)	2
		1979	10,601.3	237.2	(D)	(D)	(D)	(D)	14.3	7.0	4.3	3.0	(X)	9	(X)	4
		1978	9,950.7	253.9	(D)	(D)	(D)	(D)	13.2	6.0	4.6	2.7	(X)	18	(X)	2
		1977	9,050.6	181.5	4.8	2.3	0.7	1.8	11.2	4.8	3.7	2.6	-41	-2	1	3
22	Textile mill products	1981	(NA)	(NA)	48.0	27.2	16.2	4.6	108.5	18.9	60.2	29.4	-9	-6	13	5
		1980	47,397.0	1,495.0	59.5	32.5	23.6	3.5	115.8	16.6	59.3	39.9	52	14	10	7
		1979	45,135.5	1,329.3	39.2	21.9	15.2	2.1	101.7	19.0	60.2	22.5	-34	10	10	4
		1978	42,280.8	1,356.1	59.7	42.7	15.4	1.6	92.5	19.0	51.6	21.9	63	23	10	4
		1977	40,550.5	1,223.5	36.7	20.7	14.7	1.4	75.0	10.9	46.4	-31	15	7	6	
24	Lumber and wood products	1981	(NA)	(NA)	78.5	49.2	10.5	18.8	134.7	43.2	26.9	64.6	-4	4	11	7
		1980	47,193.1	2,027.8	81.5	55.8	15.6	10.1	129.1	39.6	32.9	56.4	-13	12	12	8
		1979	49,826.3	2,067.8	93.6	67.5	12.3	13.8	115.4	40.2	25.5	49.7	11	27	1	5
		1978	46,522.6	1,899.4	84.5	46.9	25.6	12.0	90.7	27.7	19.4	43.7	41	24	11	5
		1977	39,919.4	1,562.6	59.9	33.9	19.1	6.9	73.4	20.4	19.2	33.9	17	-10	10	5
25	Furniture and fixtures	1981	(NA)	(NA)	16.4	11.8	2.1	2.6	36.4	12.1	5.5	16.7	28	8	17	5
		1980	22,314.7	595.1	12.8	9.4	1.4	2.0	31.9	12.2	4.9	14.8	-43	9	10	5
		1979	21,067.0	525.6	22.4	16.8	2.1	3.5	29.3	11.9	4.5	12.9	100	11	13	7
		1978	19,565.9	520.8	11.2	9.4	1.1	0.7	26.4	9.1	4.0	13.4	-3	10	13	7
		1977	16,978.0	388.7	11.5	9.7	1.3	0.5	23.9	10.3	3.7	10.0	-59	11	12	7
26	Paper and allied products	1981	(NA)	(NA)	285.5	168.0	86.5	31.1	829.7	211.8	469.9	148.0	-16	9	2	2
		1980	72,595.4	5,213.3	339.6	197.4	111.2	31.0	762.1	196.2	436.7	129.1	-20	9	2	6
		1979	^{r}65,199.4	^{r}4,447.0	426.4	207.0	180.6	38.8	698.2	176.6	400.5	121.1	25	12	1	2
		1978	57,000.0	3,736.3	341.6	123.9	189.0	28.7	622.0	158.4	357.6	105.6	-20	18	1	2
		1977	52,085.7	3,295.0	427.4	134.1	261.7	31.6	529.0	133.5	309.0	86.4	-12	23	2	2
27	Printing and publishing	1981	(NA)	(NA)	12.9	9.3	1.9	1.7	63.3	15.1	17.7	30.5	1	25	8	25
		1980	69,563.9	2,813.3	12.8	9.0	1.7	2.1	50.6	13.3	9.8	27.5	-46	2	11	6
		1979	62,667.4	^{r}2,449.0	23.8	19.4	1.9	2.5	49.5	9.5	9.4	30.6	95	33	7	9
		1978	56,064.1	2,208.4	12.2	7.4	3.6	1.1	37.3	7.9	6.9	22.5	63	24	11	6
		1977	49,716.2	1,597.8	7.5	3.1	2.5	1.9	30.1	7.0	6.3	16.8	70	9	10	7
28	Chemical and allied products	1981	(NA)	(NA)	752.8	335.0	322.2	95.6	2,047.8	571.7	1,069.1	406.9	-4	11	1	2
		1980	161,558.5	8,762.5	780.7	325.9	350.0	104.8	1,851.8	539.9	942.9	368.8	1	11	3	1
		1979	147,673.7	7,976.0	770.9	314.6	360.7	95.6	1,667.5	485.3	895.2	287.0	-7	13	1	9
		1978	^{r}129,357.3	^{r}7,918.5	827.5	376.3	385.9	65.1	1,473.0	398.8	794.1	280.1	-16	19	3	2
		1977	118,153.6	8,198.9	982.5	339.9	593.1	49.6	1,283.3	335.5	685.2	217.6	4	26	1	1
29	Petroleum and coal products	1981	(NA)	(NA)	590.6	440.8	131.7	18.2	1,685.5	1,118.0	437.2	130.2	11	19	1	1
		1980	198,673.1	3,614.5	531.9	402.3	114.2	15.4	1,418.0	910.1	406.9	101.0	-1	21	3	1
		1979	^{r}148,366.5	3,272.9	534.3	397.8	119.4	17.1	1,173.8	750.7	370.8	52.3	27	18	8	7
		1978	103,871.1	2,286.1	419.3	311.2	100.5	7.6	997.4	636.4	304.1	57.0	14	5	2	1
		1977	97,452.7	2,761.3	368.5	167.7	195.6	5.3	948.0	601.3	289.3	57.4	-17	22	1	1
30	Rubber, miscellaneous plastics products	1981	(NA)	(NA)	27.8	15.3	5.9	6.5	118.3	29.8	29.6	58.8	28	9	10	1
		1980	47,341.8	2,087.0	21.7	12.6	6.9	2.3	108.2	30.4	27.6	50.2	-14	-3	13	4
		1979	46,847.9	2,208.2	25.1	12.9	9.3	2.9	111.7	32.2	29.6	49.9	-9	32	9	4
		1978	43,195.8	2,254.8	27.7	18.7	5.6	3.4	84.9	17.7	23.9	43.3	-24	15	6	3
		1977	39,552.8	1,645.3	36.6	17.4	13.8	5.4	73.8	19.8	18.9	35.1	-2	-8	6	3
31	Leather and leather products	1981	(NA)	(NA)	(D)	(D)	(D)	(D)	(S)	(S)	(S)	(S)	(X)	(X)	(X)	(X)
		1980	9,789.3	148.6	(S)	(S)	(S)	(S)	26.3	1.1	14.4	10.7	(X)	17	(X)	19
		1979	9,002.6	130.3	(D)	(D)	(D)	(D)	22.5	1.3	14.6	6.6	(X)	16	(X)	16
		1978	8,224.7	135.1	(S)	(S)	(S)	(S)	19.3	1.4	11.3	6.6	(X)	25	(X)	16
		1977	7,607.4	96.2	11.4	1.8	9.3	0.4	15.4	1.1	9.1	5.2	-34	40	48	16
32	Stone, clay, glass products	1981	(NA)	(NA)	188.5	165.6	13.8	9.2	310.7	191.0	47.5	72.2	25	3	12	4
		1980	66,083.1	3,037.8	151.0	123.1	17.9	10.0	301.7	182.1	48.2	71.4	4	3	12	3
		1979	65,962.8	2,606.1	145.6	110.2	25.4	10.0	293.6	188.0	45.1	60.5	18	17	9	10
		1978	61,719.3	2,531.2	123.8	92.1	28.0	3.7	251.1	163.7	33.2	54.2	-7	17	7	4
		1977	55,476.6	1,881.4	133.4	85.8	39.1	8.6	214.5	141.7	28.0	44.8	27	12	17	4
33	Primary metal industries	1981	(NA)	(NA)	728.2	567.2	144.1	16.9	1,911.8	1,111.9	549.2	250.7	-2	14	1	1
		1980	133,930.1	5,495.9	740.0	539.7	180.7	19.6	1,676.8	998.2	463.2	215.3	-10	6	1	1
		1979	137,379.4	^{r}5,129.3	823.1	588.8	227.3	6.9	1,587.2	981.7	442.0	163.5	4	20	1	1
		1978	118,082.0	4,691.9	791.8	563.3	219.1	9.4	1,321.4	809.6	333.0	178.9	-9	18	1	1
		1977	103,179.4	4,496.8	874.6	616.0	250.2	8.4	1,122.3	721.6	268.3	132.3	5	25	2	1
34	Fabricated metal products	1981	(NA)	(NA)	75.4	37.4	30.4	7.6	230.5	51.6	93.4	85.0	-1	5	7	3
		1980	116,194.3	3,919.0	76.4	37.5	34.8	4.2	219.2	49.0	88.2	81.9	16	-1	6	4
		1979	113,197.2	^{r}3,365.2	66.1	36.7	24.5	4.9	220.9	57.0	99.7	64.2	7	31	5	1
		1978	101,336.0	3,189.1	61.6	33.1	26.2	2.3	168.7	42.1	73.8	52.8	-20	13	8	15
		1977	90,023.5	2,606.1	76.7	32.5	39.2	5.0	149.2	40.3	66.1	42.8	5	20	7	3
35	Machinery, except electrical	1981	(NA)	(NA)	67.1	30.9	28.0	8.2	220.9	47.3	81.6	91.7	-10	7	2	9
		1980	180,727.3	7,934.2	74.5	36.0	34.9	3.6	206.4	48.0	73.0	85.3	-12	3	17	3
		1979	166,470.2	6,817.0	84.3	38.3	38.2	7.8	200.2	50.1	69.0	81.1	4	26	2	1
		1978	141,109.3	5,739.7	81.5	41.6	27.8	12.6	138.8	41.0	36.4	61.1	-10	17	6	12
		1977	122,187.7	4,602.4	90.2	42.3	42.4	5.5	135.6	33.1	49.8	52.6	30	15	3	2

See footnotes at end of table.

Table 1A. Pollution Abatement Capital Expenditures and Operating Costs, by Form of Abatement and Major Industry Group: 1977 to 1981—Continued

(In millions of dollars, except percents)

SIC code	Industry		Annual Survey of Manufactures (ASM)[1]		Pollution abatement capital expenditures (PACE)				Pollution abatement gross annual costs (GAC) including payments to government units				Percent change (prior year to current year)		Standard error of estimates (percent)	
			Total value of shipments	Total new capital expenditures	Total	Air	Water	Solid waste	Total	Air	Water	Solid waste	PACE	GAC	PACE	GAC
36	Electric, electronic equipment	1981	(NA)	(NA)	97.1	48.7	41.0	7.4	247.1	51.8	106.2	88.8	23	21	3	2
		1980	128,587.3	6,162.0	79.0	43.5	27.1	8.4	205.0	45.2	87.8	71.9	-13	12	3	1
		1979	116,031.9	4,565.7	90.9	41.8	42.0	7.1	182.3	46.7	82.8	52.8	26	23	5	1
		1978	100,530.1	3,699.7	72.2	32.9	36.0	3.3	148.6	30.7	71.7	46.1	13	16	5	2
		1977	88,433.1	2,866.5	63.8	23.0	36.0	4.9	128.3	28.0	63.2	37.1	9	17	4	2
37	Transportation equipment	1981	(NA)	(NA)	283.3	209.2	60.0	14.2	426.1	117.5	150.7	157.7	3	6	1	1
		1980	186,281.7	8,002.4	275.0	201.4	60.7	12.9	401.5	110.7	137.4	153.2	45	21	1	1
		1979	201,625.0	6,853.8	189.5	120.1	59.5	9.9	331.8	96.4	126.3	109.1	36	18	1	1
		1978	188,773.3	5,834.3	139.5	71.0	57.9	10.7	280.5	77.3	110.2	93.0	69	20	1	1
		1977	166,956.0	4,670.9	82.6	36.9	39.6	6.3	233.9	60.6	97.3	76.1	5	18	1	1
38	Instruments, related products	1981	(NA)	(NA)	40.1	14.4	23.7	2.1	90.4	12.8	40.0	37.5	67	17	4	2
		1980	44,138.7	1,701.3	27.2	11.3	12.7	3.2	77.1	11.3	33.7	32.1	17	11	9	1
		1979	37,740.2	r1,419.2	23.2	13.0	7.7	2.5	69.7	10.6	30.7	27.9	37	23	12	1
		1978	33,701.2	1,099.3	16.9	6.8	9.5	0.6	55.8	7.3	26.9	21.6	-31	18	2	2
		1977	28,897.8	938.9	24.4	14.5	8.5	1.4	47.3	9.0	23.0	15.4	-24	4	4	2
39	Miscellaneous manufacturing industries	1981	(NA)	(NA)	11.5	6.7	3.9	0.9	28.6	6.2	7.9	14.1	5	8	19	5
		1980	25,031.6	731.8	11.0	6.4	4.2	0.5	26.3	5.2	7.2	13.8	(X)	-	19	5
		1979	23,015.6	595.4	(S)	(S)	(S)	(S)	26.3	6.5	7.2	12.6	(X)	19	(X)	16
		1978	20,779.6	531.3	(S)	(S)	(S)	(D)	22.1	4.0	5.8	12.3	(X)	16	(X)	4
		1977	19,150.7	473.6	6.6	2.5	3.9	0.3	19.0	5.3	5.2	8.4	35	15	28	5

Note: Totals may not agree with detail because of independent rounding. For data prior to 1977, see MA-200(80)-1. Statistics in other than the first two columns in this table cover manufacturing establishments with 20 employees or more. See text for a description of survey coverage.

[1] Data from the Annual Survey of Manufactures includes establishments with fewer than 20 employees. These data also include major industry group 23, Apparel and Other Textile Products.

[2] Excludes major industry group 23, Apparel and Other Textile Products.

Economics Department

McGraw-Hill Publications Company
1221 Avenue of the Americas
New York, New York 10020

May, 1983

16TH ANNUAL McGRAW-HILL SURVEY OF POLLUTION CONTROL EXPENDITURES, 1983-86

Executive Summary

American business plans to reduce its capital investment in pollution control equipment by 4.9% this year to $9 billion. In comparison, plans for total business spending on capital goods is expected to drop 1.3% in 1983.

If all plans are realized, pollution control spending as a share of total capital spending would drop to 2.9% in 1983 from 3.0% in 1982. This projected decline continues a seven-year trend in which smaller and smaller proportions of capital budgets have been allocated to pollution control. The proportion peaked at 5.6% in 1976.

These are some of the major findings of the 16th annual McGraw-Hill survey of firms' plans to purchase pollution control equipment. The survey, conducted during March and April, drew responses from 450 companies, accounting for one-third of the nation's capital expenditures.

The survey shows that pollution control equipment spending is expected to continue to decline in relative importance over the next few years. From 1984 to 1986, planned pollution control expenditures average $8.5 billion per year, only about 2.4% of all capital spending plans. If realized, that would be the smallest share of capital spending going to pollution control equipment since 1969.

Economics Department

McGraw-Hill Publications Company
1221 Avenue of the Americas
New York, New York 10020

May, 1983

16TH ANNUAL McGRAW-HILL SURVEY OF POLLUTION CONTROL EXPENDITURES, 1983-86

American business plans to decrease its capital investment in pollution control equipment by 4.9% this year to $9 billion (Table I). These plans represent an inflation-adjusted decrease of close to 10%. In comparison, plans for total business spending on capital goods is expected to drop 1.3% in 1983, according to McGraw-Hill's annual spring survey of plant and equipment expenditures.

If realized, the planned decrease in purchases of equipment used to combat air, water, and solid waste pollution would mark the second consecutive yearly decline. In 1982, pollution control expenditures fell to $9.39 billion from $9.56 billion in 1981. This year, the decline is somewhat steeper. Moreover, projected 1983 outlays are well below the peak $10.9 billion reached in 1977.

If the current 1983 investment target is met, the proportion of capital investment allocated to pollution control equipment would fall, continuing a trend that began seven years ago. In 1983, business estimates that 2.9% of capital spending will be devoted to pollution control equipment, compared to 3.0% last year and a high of 5.6% in 1976 (Tables III and VI).

These are some of the major findings of the 16th annual McGraw-Hill survey of firms' plans to purchase pollution control equipment. The survey, conducted during March and April, drew responses from 450 companies, accounting for one-third of the nation's capital expenditures. However, the figures provided represent spending for entire industries, not just for those companies that responded to the survey.

One conclusion to be drawn from the survey is that investment in pollution abatement equipment is becoming less of a priority for U.S. business. Because the 1981-1982 recession forced sharp cutbacks in all discretionary capital spending, it should come as no surprise that pollution control spending has taken some lumps. In addition, since the election of President Reagan, environmental regulation has ceased to mount.

The survey also shows that pollution control equipment spending is expected to continue to decline in relative importance over the next few years. During the period from 1984 to 1986, planned pollution control expenditures average $8.5 billion per year, only about 2.4% of all capital spending plans. If realized, that would be the lowest allocation of capital spending to pollution control equipment since 1969.

Part of the increase in the proportion of spending devoted to pollution control during the early and mid-1970s resulted from industry's bringing plants in line with the then newly enacted Clean Air Act and other environmental regulations. By now, however, industry has closed the gap between its environmental practices and those required by governmental regulation. Therefore, even if there is no relaxation of existing regulations, pollution control expenditures would likely continue to decline in importance relative to total capital spending.

Industry and Sector Spending

As usual, the largest capital expenditures for pollution control equipment are planned by the electric utilities. In 1983, $2.5 billion in expenditures are planned. However, that planned spending is 14.2% lower than electric utilities spent on pollution control equipment in 1982. Since electric utilities are by far the largest pollution control equipment spenders, that 14% decline plays a large role in explaining the decline in total pollution control expenditures. In fact, excluding electric utilities, business projects only a 0.5% expenditure decline.

For 1983, the only other industry with a pollution control capital budget above $1 billion is the petroleum industry. Like the electric utilities though, the petroleum industry has also planned a sharp cutback in pollution control capital spending. Other industries with a large share of their capital budgets going to pollution control equipment (Table III) include nonferrous metals (11.3%), paper and pulp (8.7%) and other nondurables (8.3%).

Manufacturers plan to decrease their pollution control capital spending significantly less than do nonmanufacturers. Manufacturers plan to reduce their spending by only 0.2% while nonmanufacturers plan to spend 9.8% less in 1983. Of the various nonmanufacturing industries surveyed, only railroads, gas utilities, and trade and services plan to increase spending.

The largest percentage increase in pollution control expenditures planned in 1983 is by the autos, trucks, and parts industry, up 255%. But the increase is from a very small base. Other large percentage increases were reported by stone, clay, and glass (91.4%), paper and pulp (75.7%), and other nondurables (65.1%).

At the same time, several industries planned sharp cutbacks in pollution control investment. The largest decline was reported by the iron and steel industry, down by 50.5%. Other large declines were in the food and beverage industry (-25.3%), mining (-25.7%), and airlines (-25.0%).

Air, Water Solid Waste Spending

As in the past, the lion's share of pollution control expenditures in 1983 will go to equipment used to reduce air pollution. However, the importance of air pollution expenditures is declining relative to spending on water pollution and solid waste disposal. In 1983, plans for air pollution abatement spending represent 44.1% of all planned pollution control capital spending. In 1982, air pollution spending was over 49% of the total. In all, planned air pollution capital expenditures are 14.4% lower than 1982 (Table II).

While spending on equipment to combat air pollution has declined, increases in spending are planned for spending on equipment to control water and solid waste pollution. Next year's targets call for water pollution control expenditures to be up 1.1% and solid waste pollution control expenditures to be up 12.1%. Over the next few years, business expects to spend more on solid waste control equipment, while investing less in air and water pollution control.

Much of the increase in water pollution expenditures can be attributed to large spending increases by a few industries-- paper and pulp (82.8%), stone clay and glass (209.1%), and railroads(46.8%).

Large increases in solid waste pollution control equipment are projected by the autos, trucks and parts industry, paper and pulp, and stone clay and glass.

Given these projected increases, water pollution control equipment's share in total pollution abatement investment should rise to 36.8% in 1983, compared to 34.7% last year. The share is expected to rise to 37.2% in 1984 through 1986. For solid waste expenditures, the projected share for 1983 is 19.1%, versus 16.3% in 1982, rising to 22.4% in 1984-1986.

TABLE I

INVESTMENT FOR POLLUTION CONTROL
(Millions of Dollars)

INDUSTRY	Actual 1982	Planned 1983	% Change 1982-83	Planned 1984-85 (Annual Average)
Iron & Steel	$ 289	$ 143	-50.5%	$ 248
Nonferrous Metals	219	200	-8.7	251
Electrical Machinery	236	245	3.8	317
Machinery	197	173	-12.2	318
Autos, Trucks & Parts	20	71	255.0	140
Aerospace	128	153	19.5	164
Fabricated Metals	45	62	37.8	50
Instruments	96	127	32.3	262
Stone, Clay & Glass	81	155	91.4	192
Other Durables	154	171	11.0	220
TOTAL DURABLES	1,465	1,500	2.4	2,162
Chemicals	954	794	-16.8	1,268
Paper & Pulp	313	550	75.7	359
Rubber	76	62	-18.4	96
Petroleum	1,252	1,038	-17.1	473
Food & Beverages	530	396	-25.3	370
Textiles	63	70	11.1	70
Other Nondurables	358	591	65.1	339
TOTAL NONDURABLES	3,546	3,501	-1.3	2,975
ALL MANUFACTURING	5,011	5,001	-0.2	5,137
Mining	561	417	-25.7	404
Railroads	184	257	39.7	250
Airlines	140	105	-25.0	75
Electric Utilities	2,889	2,479	-14.2	1,766
Gas Utilities	23	25	8.7	32
Communications & Other	191	170	-11.0	220
Trade & Services	394	499	26.6	620
ALL NONMANUFACTURING	4,382	3,952	-9.8	3,367
ALL BUSINESS	9,393	8,953	-4.9	8,504

NOTE: The other durables category listed in the tables includes lumber, furniture, jewelry, toys, and transportation equipment other than autos and aerospace. Other nondurables includes apparel, tobacco, printing and publishing, and leather.

TABLE II

POLLUTION CONTROL EXPENDITURES - AIR, WATER, AND SOLID WASTE
(Millions of Dollars)

INDUSTRY	---------1982--------			----1983 Planned-----			-% Change, 1982-83-			Planned 1984-86 ----Annual Average----		
	Air	Water	Solid Waste	Air	Water	Solid Waste	Air	Water	Solid Waste	Air	Water	Solid Waste
Iron & Steel	$ 151	$ 133	$ 5	$ 86	$ 53	$ 4	-43.0%	-60.2%	-20.0%	$ 99	$ 143	$ 6
Nonferrous Metals	35	150	34	35	136	29	0	-9.3	-14.7	27	191	33
Electrical Machinery	55	137	44	70	121	54	27.3	-11.7	22.7	109	137	71
Machinery	94	87	16	49	100	24	-47.9	14.9	50.0	147	141	30
Autos, Trucks & Parts	9	9	2	35	9	27	288.9	0	1,250.0	106	12	22
Aerospace	39	50	39	39	47	67	0	6.0	71.8	43	53	68
Fabricated Metals	10	27	8	9	41	12	-10.0	51.9	50.0	12	25	13
Instruments	27	46	23	36	59	32	33.3	28.3	39.1	78	110	74
Stone, Clay & Glass	42	22	17	48	68	39	14.3	209.1	129.4	78	57	57
Other Durables	70	50	34	72	56	43	2.9	12.0	26.5	124	45	51
TOTAL DURABLES	532	711	222	479	690	331	-10.0	-3.0	49.1	823	914	425
Chemicals	438	340	176	309	291	194	-29.5	-14.4	10.2	416	667	185
Paper & Pulp	103	134	76	165	245	140	60.2	82.8	84.2	151	105	103
Rubber	32	30	14	22	23	17	-31.3	-23.3	21.4	38	32	26
Petroleum	654	494	104	401	529	108	-38.7	7.1	3.8	164	185	124
Food & Beverages	180	180	170	159	130	1,017	-11.7	-27.8	-37.1	122	136	112
Textiles	31	23	9	30	28	12	-3.2	21.7	33.3	27	26	17
Other Nondurables	238	60	60	442	75	74	85.7	25.0	23.3	169	85	85
TOTAL NONDURABLES	1,676	1,261	609	1,528	1,321	652	-8.8	4.8	7.1	1,087	1,236	652
ALL MANUFACTURING	2,208	1,972	831	2,007	2,011	983	-9.1	2.0	18.3	1,910	2,150	1,077
Mining	162	218	181	47	211	159	-71.0	-3.2	-12.2	49	223	132
Railroads	29	126	29	36	185	36	24.1	46.8	24.1	51	148	51
Airlines	90	25	25	43	31	31	-52.2	24.0	24.0	39	18	18
Electric Utilities	1,879	775	235	1,577	689	213	-16.1	-11.1	-9.4	1,094	427	245
Gas Utilities	0	6	17	0	6	19	0	0	11.8	0	8	24
Communications & Other	85	85	21	80	80	10	-5.9	-5.9	-52.4	104	104	12
Trade & Services	156	48	190	157	79	263	0.6	64.6	38.4	191	85	344
ALL NONMANUFACTURING	2,401	1,283	698	1,940	1,281	731	-19.2	-0.2	4.7	1,528	1,013	826
ALL BUSINESS	4,609	3,255	1,529	3,947	3,292	1,714	-14.4	1.1	1	3,438	3,163	1,903

TABLE III

POLLUTION CONTROL EXPENDITURES AS PERCENT OF CAPITAL SPENDING

INDUSTRY	Actual 1982	Planned 1983	Planned 1984-86 (Annual Average)
Iron & Steel	8.3%	5.7%	6.3%
Nonferrous Metals	8.1	11.3	10.1
Electrical Machinery	2.2	2.1	2.0
Machinery	1.5	1.4	1.9
Autos, Trucks & Parts	0.3	0.8	1.3
Aerospace	2.1	2.3	2.5
Fabricated Metals	1.7	2.3	1.8
Instruments	4.1	4.4	7.0
Stone, Clay & Glass	3.1	5.6	6.0
Other Durables	2.9	3.6	3.6
TOTAL DURABLES	2.6	2.7	3.0
Chemicals	7.2	6.5	8.9
Paper & Pulp	5.2	8.7	5.9
Rubber	4.4	3.1	3.8
Petroleum	4.7	4.2	1.6
Food & Beverages	6.8	5.3	4.6
Textiles	4.7	5.5	5.6
Other Nondurables	5.5	8.3	4.2
TOTAL NONDURABLES	5.6	5.7	4.3
ALL MANUFACTURING	4.2	4.2	3.6
Mining	3.6	3.3	2.8
Railroads	4.2	5.5	4.0
Airlines	3.6	3.0	3.1
Electric Utilities	8.6	7.1	5.6
Gas Utilities	0.3	0.4	0.4
Communications & Other	0.4	0.4	0.4
Trade & Services	0.5	0.6	0.6
ALL NONMANUFACTURING	2.2	2.0	1.5
ALL BUSINESS	3.0	2.9	2.4

TABLE IV

TOTAL POLLUTION CONTROL EXPENDITURES--HISTORICAL
(Millions of Dollars)

INDUSTRY	1967	1968	1969	1970	1971	1972	1973	1974	1975
Iron & Steel	$ 114	$ 105	$ 154	$ 168	$ 163	$ 132	$ 146	$ 180	$ 450
Nonferrous Metals	44	16	39	96	105	148	234	580	597
Electrical Machinery	31	95	52	80	70	79	130	89	132
Machinery	30	61	54	132	107	123	167	214	114
Autos, Trucks & Parts	114	53	99	128	162	198	429	456	191
Aerospace	13	23	35	25	30	42	87	30	77
Other Transportation Equipment	7	15	39	36	30	15	41	67	31
Fabricated Metals	26	46	43	52	85	104	130	109	213
Instruments	6	15	30	31	72	28	33	57	58
Stone, Clay & Glass	46	42	63	68	124	129	142	287	292
Other Durables	64	76	134	177	117	99	164	247	182
TOTAL DURABLES	495	547	742	993	1,065	1,097	1,705	2,316	2,337
Chemicals	92	109	135	166	268	368	432	472	679
Paper & Pulp	89	79	147	162	266	340	454	480	653
Rubber	7	10	9	49	43	60	96	47	56
Petroleum	97	159	242	310	469	513	594	526	1,228
Food & Beverages	41	22	61	100	127	171	228	536	213
Textiles	8	11	14	18	30	28	36	59	80
Other Nondurables	61	28	49	103	20	110	78	53	32
TOTAL NONDURABLES	395	418	657	908	1,223	1,590	1,918	2,173	2,941
ALL MANUFACTURING	890	965	1,399	1,901	2,288	2,687	3,623	4,489	5,278
Mining	55	49	99	108	75	147	252	323	500
Railroads	NA	NA	NA	31	21	27	47	51	58
Airlines	NA	NA	NA	20	10	52	194	178	23
Other Transportation	0	0	0	7	144	23	63	75	360
Communications	0	0	0	*	*	215	422	1,118	305
Electric Utilities	146	231	154	401	540	1,074	1,140	1,181	1,515
Gas Utilities	81	25	130	108	48	43	45	70	43
Trade & Services	0	0	0	179	445	480	592	860	555
ALL NONMANUFACTURING	282	305	383	854	1,283	2,061	2,755	3,856	3,357
ALL BUSINESS	1,172	1,270	1,782	2,755	3,571	4,748	6,378	8,345	8,637

NA - Not Available
* Less than $500,000

TABLE IV

TOTAL POLLUTION CONTROL EXPENDITURES--HISTORICAL
(Millions of Dollars)
(Continued)

INDUSTRY	1976	1977	1978	1979	1980	1981
Iron & Steel	$ 620	$ 466	$ 436	$ 615	$ 503	$ 415
Nonferrous Metals	402	547	253	182	247	234
Electrical Machinery	176	126	193	204	198	132
Machinery	227	435	281	231	200	357
Autos, Trucks & Parts	174	221	303	677	701	150
Aerospace	76	66	97	58	37	138
Other Transportation Equipment**	52	41	66	---	---	---
Fabricated Metals	250	144	150	119	99	70
Instruments	62	41	64	95	72	128
Stone, Clay & Glass	168	164	260	142	193	157
Other Durables	167	146	166	228	202	334
TOTAL DURABLES	2,374	2,397	2,269	2,571	2,452	2,115
Chemicals	999	855	651	744	961	900
Paper & Pulp	799	468	315	438	458	328
Rubber	75	195	120	102	49	63
Petroleum	808	1,053	753	1,151	877	1,355
Food & Beverages	350	266	376	218	200	342
Textiles	132	76	108	132	85	77
Other Nondurables	51	139	103	124	173	55
TOTAL NONDURABLES	3,214	3,052	2,426	2,909	2,803	3,120
ALL MANUFACTURING	5,588	5,449	4,695	5,480	5,255	5,235
Mining	513	1,617	1,092	182	194	983
Railroads	32	55	56	64	158	81
Airlines	21	37	31	112	75	3
Other Transportation**	253	97	74	72	--	--
Communications	352	242	318	309	80	164
Electric Utilities	2,156	2,356	2,143	2,959	2,592	2,956
Gas Utilities	127	173	69	44	*	*
Trade & Services	641	906	1,192	1,158	834	142
ALL NONMANUFACTURING	4,095	5,483	4,975	4,900	3,933	4,329
ALL BUSINESS	9,683	10,932	9,670	10,380	9,188	9,564

NA - Not Available
* Less than $500,000
** As of 1979, other transportation equipment is included in other durables. As of 1980, other transportation services are included with communications.

TABLE V

HISTORICAL POLLUTION CONTROL EXPENDITURES -- AIR WATER, SOLID WASTE
(Millions of Dollars)

INDUSTRY	1970 Air	1970 Water	1971 Air	1971 Water	1972 Air	1972 Water	1973 Air	1973 Water
Iron & Steel	$ 70	$ 98	$ 84	$ 79	$ 71	$ 61	$ 65	$ 81
Nonferrous Metals	77	19	78	27	123	25	199	35
Electrical Machinery	38	42	36	34	37	42	59	71
Machinery	89	43	70	37	64	59	92	75
Autos, Trucks & Parts	86	42	101	61	117	81	236	193
Aerospace	15	10	22	8	24	18	54	35
Other Transportation Equipment	29	7	22	8	12	3	32	9
Fabricated Metals	25	27	65	20	64	40	51	79
Instruments	22	9	30	42	10	18	21	12
Stone, Clay & Glass	41	27	94	30	81	48	94	48
Other Durables	76	101	53	64	73	26	111	53
TOTAL DURABLES	568	425	655	410	676	421	1,014	691
Chemicals	78	88	118	150	159	209	174	258
Paper & Pulp	62	100	126	140	182	158	294	160
Rubber	31	18	20	23	30	30	69	27
Petroleum	140	170	250	219	340	173	379	215
Food & Beverages	45	55	54	73	83	88	120	108
Textiles	6	12	8	22	13	15	13	23
Other Nondurables	7	96	12	8	58	52	65	13
TOTAL NONDURABLES	369	539	588	635	865	725	1,114	804
ALL MANUFACTURING	937	964	1,243	1,045	1,541	1,146	2,128	1,495
Mining	69	39	36	39	97	50	194	58
Railroads	23	8	8	13	8	19	23	24
Airlines	17	3	10	*	48	4	194	0
Other Transportation	5	2	83	61	10	13	54	9
Communications	*	*	*	*	72	143	211	211
Electric Utilities	253	148	319	221	856	218	795	345
Gas Utilities	74	34	26	22	24	19	24	21
Trade & Services	90	89	274	171	280	200	500	92
ALL NONMANUFACTURING	531	323	756	527	1,395	636	1,995	760
ALL BUSINESS	1,468	1,287	1,999	1,572	2,936	[illegible]	4,123	2,255

* Less than $500,000

TABLE V

HISTORICAL POLLUTION CONTROL EXPENDITURES -- AIR WATER, SOLID WASTE
(Millions of Dollars)
(Continued)

INDUSTRY	1974		1975			1976		
	Air	Water	Air	Water	Solid Waste	Air	Water	Solid Waste
Iron & Steel	$ 104	$ 76	$ 199	$ 172	$ 79	$ 428	$ 188	$ 4
Nonferrous Metals	400	180	468	54	75	323	41	38
Electrical Machinery	46	43	38	69	25	43	99	34
Machinery	119	95	49	54	11	133	77	17
Autos, Trucks & Parts	254	202	67	64	60	109	43	22
Aerospace	19	11	37	29	11	34	27	15
Other Transportation Equipment	67	*	17	7	7	14	9	29
Fabricated Metals	80	29	98	103	12	94	147	9
Instruments	28	29	25	27	6	15	34	13
Stone, Clay & Glass	180	107	162	70	60	129	31	8
Other Durables	158	89	138	35	9	94	56	17
TOTAL DURABLES	1,455	861	1,298	684	355	1,416	752	206
Chemicals	207	265	259	329	91	292	601	106
Paper & Pulp	284	196	405	239	9	258	419	122
Rubber	20	27	30	15	11	49	25	1
Petroleum	365	161	691	345	192	453	313	42
Food & Beverages	133	403	92	96	25	120	148	82
Textiles	33	26	26	42	12	26	88	18
Other Nondurables	33	20	23	8	1	20	21	10
TOTAL NONDURABLES	1,075	1,098	1,526	1,074	341	1,218	1,615	381
ALL MANUFACTURING	2,530	1,959	2,824	1,758	696	2,634	2,367	587
Mining	202	121	291	135	74	348	106	59
Railroads	16	35	11	41	6	6	23	3
Airlines	166	12	10	12	1	16	4	1
Other Transportation	43	32	199	111	50	140	93	20
Communications	536	582	87	130	88	48	234	70
Electric Utilities	715	466	999	400	116	1,462	507	187
Gas Utilities	42	28	20	9	14	72	47	8
Trade & Services	526	334	277	139	139	394	148	99
ALL NONMANUFACTURING	2,246	1,610	1,894	977	488	2,486	1,162	447
ALL BUSINESS	4,776	3,569	4,718	2,735	1,184	5,120	3,529	1,034

* Less than $500,000

TABLE V

HISTORICAL POLLUTION CONTROL EXPENDITURES -- AIR WATER, SOLID WASTE
(Millions of Dollars)
(Continued)

INDUSTRY	1977 Air	1977 Water	1977 Solid Waste	1978 Air	1978 Water	1978 Solid Waste	1979 Air	1979 Water	1979 Solid Waste
Iron & Steel	$ 234	$ 182	$ 50	$ 285	$ 148	$ 3	$ 457	$ 157	$ 1
Nonferrous Metals	363	173	11	202	28	23	86	53	43
Electrical Machinery	47	47	32	85	66	42	55	91	58
Machinery	204	204	27	139	109	33	84	140	7
Autos, Trucks & Parts	76	76	69	294	5	4	231	231	235
Aerospace	29	27	10	56	24	17	16	24	18
Other Transportation Equipment**	15	11	15	20	20	26	---	---	---
Fabricated Metals	97	45	2	90	41	19	53	35	31
Instruments	15	22	4	39	21	4	36	33	26
Stone, Clay & Glass	85	49	30	132	70	58	79	42	21
Other Durables	85	38	23	78	33	55	73	75	80
TOTAL DURABLES	1,250	874	273	1,420	565	284	1,170	881	520
Chemicals	277	513	65	251	334	66	299	326	119
Paper & Pulp	191	223	54	155	156	4	200	154	84
Rubber	131	56	8	91	11	18	56	24	22
Petroleum	495	495	63	320	340	93	636	450	65
Food & Beverages	102	133	31	131	163	82	87	93	38
Textiles	33	30	13	37	67	4	13	101	18
Other Nondurables	21	99	19	31	48	24	51	34	39
TOTAL NONDURABLES	1,250	1,549	253	1,016	1,119	291	1,342	1,182	385
ALL MANUFACTURING	2,500	2,423	526	2,436	1,684	575	2,512	2,063	905
Mining	358	1,200	59	494	241	357	60	62	60
Railroads	6	37	12	9	36	11	13	41	10
Airlines	20	13	4	19	8	4	65	29	18
Other Transportation**	56	41	*	34	38	2	33	37	2
Communications	54	162	26	71	213	34	69	207	33
Electric Utilities	1,579	689	88	1,188	883	72	1,808	1,006	145
Gas Utilities	88	83	2	24	36	9	8	34	2
Trade & Services	452	227	227	596	298	298	580	290	290
ALL NONMANUFACTURING	2,613	2,452	418	2,435	1,753	787	2,636	1,700	560
ALL BUSINESS	5,113	4,875	944	4,871	3,437	1,362	5,148	3,763	1,465

---

* Less than $500,000

** As of 1979, other transportation equipment is included in other durables. As of 1980, other transportation services are included with communications.

TABLE V

HISTORICAL POLLUTION CONTROL EXPENDITURES -- AIR WATER, SOLID WASTE
(Millions of Dollars)
(Continued)

INDUSTRY	1980 Air	1980 Water	1980 Solid Waste	1981 Air	1981 Water	1981 Solid Waste
Iron & Steel	$ 314	$ 155	$ 35	$ 248	$ 147	$ 20
Nonferrous Metals	144	45	58	119	73	42
Electrical Machinery	78	67	52	37	83	12
Machinery	71	127	2	186	162	9
Autos, Trucks & Parts	350	175	176	50	50	50
Aerospace	16	12	9	46	47	45
Other Transportation Equip.	--	--	--	--	--	--
Fabricated Metals	33	58	8	22	29	19
Instruments	36	20	16	34	65	29
Stone, Clay & Glass	111	43	39	92	55	10
Other Durables	111	52	39	134	124	76
TOTAL DURABLES	1,264	754	434	968	835	312
Chemicals	316	428	217	240	473	187
Paper & Pulp	210	187	61	183	141	4
Rubber	8	27	14	26	27	10
Petroleum	388	464	24	653	644	58
Food & Beverages	48	78	74	134	142	66
Textiles	35	29	21	30	34	13
Other Nondurables	59	57	57	18	18	19
TOTAL NONDURABLES	1,064	1,270	468	1,284	1,479	357
ALL MANUFACTURING	2,328	2,024	902	2,252	2,314	669
Mining	125	10	59	297	451	235
Railroads	5	63	90	33	30	18
Airlines	27	28	20	1	1	1
Other Transportation**	--	--	--	--	--	--
Electric Utilities	1,394	947	252	2,107	618	231
Gas Utilities	*	*	*	*	*	*
Communications & Other	36	34	11	43	106	15
Trade & Services	209	317	309	29	24	89
ALL NONMANUFACTURING	1,796	1,399	741	2,510	1,230	589
ALL BUSINESS	4,124	3,423	1,643	4,762	3,544	1,258

---

* Less than $500,000
NA - Not Applicable

TABLE VI

POLLUTION CONTROL EXPENDITURES AS A PERCENT OF CAPITAL SPENDING--HISTORICAL
(Percent)

INDUSTRY	1967	1968	1969	1970	1971	1972	1973	1974	1975**	1976
Iron & Steel	6.0%	5.2%	8.4%	10.3%	12.8%	12.3%	11.7%	9.3%	14.9%	20.4%
Nonferrous Metals	4.0	1.4	3.7	8.1	10.3	15.3	18.0	28.3	27.5	20.4
Electrical Machinery	1.0	3.0	1.6	2.3	2.3	2.8	3.7	2.3	4.2	4.8
Machinery	1.0	2.1	1.5	3.5	3.4	3.8	4.2	4.1	2.3	4.1
Autos, Trucks & Parts	4.0	2.0	3.3	4.2	6.7	6.6	11.2	10.6	5.7	4.8
Aerospace	1.0	1.9	2.7	2.8	4.7	6.2	10.2	2.0	4.6	4.5
Other Transportation Equipment	2.1	4.4	5.4	5.0	6.2	2.0	4.3	6.4	3.5	4.8
Fabricated Metals	2.0	3.4	3.5	4.3	7.1	7.3	7.2	5.6	10.8	11.2
Instruments	0.9	2.0	3.5	3.6	9.0	3.2	2.9	4.8	5.5	5.5
Stone, Clay & Glass	5.0	4.7	5.9	6.4	13.2	9.6	9.0	17.5	17.6	9.0
Other Durables	4.9	5.0	7.0	9.2	6.4	4.8	6.5	9.0	7.5	6.3
TOTAL DURABLES	2.8	3.1	3.7	5.0	6.3	6.0	7.5	8.4	8.9	8.3
Chemicals	3.0	3.9	4.5	4.9	8.2	10.9	10.2	7.3	8.9	12.3
Paper	6.0	6.2	9.1	9.3	20.6	23.3	22.8	16.6	21.9	25.7
Rubber	1.0	1.0	0.8	5.3	5.4	5.8	6.2	3.0	4.8	5.7
Petroleum	2.0	3.2	4.6	6.0	9.0	10.7	12.7	7.2	12.8	7.5
Food & Beverages	2.0	1.0	2.2	3.0	3.8	5.2	6.3	13.3	5.3	7.3
Textiles	1.0	1.7	1.6	2.3	3.3	2.6	3.5	5.4	8.9	12.6
Other Nondurables	4.0	1.8	2.8	5.5	1.0	5.0	3.1	2.2	1.4	2.2
TOTAL NONDURABLES	2.7	2.9	4.0	5.3	7.3	9.2	9.8	8.4	10.3	10.2
ALL MANUFACTURING	2.8	3.0	3.9	5.1	6.8	7.6	8.9	8.4	9.6	9.3
Mining	4.0	3.4	5.6	6.1	2.8	5.1	7.6	7.0	8.2	6.9
Railroads	NA	NA	NA	1.6	1.2	1.6	2.2	1.9	2.0	1.1
Airlines	NA	NA	NA	0.7	0.7	2.4	9.3	9.2	1.4	1.8
Other Transportation	0.0	0.0	0.0	0.3	5.3	0.8	2.0	2.1	8.6	5.2
Communications	0.0	0.0	0.0	0.0	*	2.4	2.0	4.8	1.4	1.5
Electric Utilities	2.0	2.9	1.7	3.8	4.4	7.9	7.6	7.1	9.1	11.5
Gas Utilities	4.0	1.0	4.9	4.4	2.0	1.6	1.5	2.2	1.3	3.5
Trade & Services	0.0	0.0	0.0	0.6	1.3	1.2	1.3	1.8	1.2	1.3
ALL NONMANUFACTURING	0.6	0.5	0.6	1.2	1.7	2.4	2.9	3.7	3.3	3.7
ALL BUSINESS	1.4	1.4	1.8	2.6	3.3	3.9	4.6	5.3	5.5	5.6

NA - Not Available
* Less than .05%
**Solid waste is included starting in 1975.

TABLE VI

POLLUTION CONTROL EXPENDITURES AS A PERCENT OF CAPITAL SPENDING--HISTORICAL
(Percent)
(Continued)

INDUSTRY	1977	1978	1979	1980	1981
Iron & Steel	16.7%	17.3%	19.9%	15.3%	13.1%
Nonferrous Metals	29.1	12.0	7.6	8.0	6.8
Electrical Machinery	2.7	3.4	2.8	2.1	1.3
Machinery	6.6	3.9	2.2	1.7	2.7
Autos, Trucks & Parts	3.8	4.2	8.4	7.7	1.5
Aerospace	3.3	3.0	1.1	0.5	2.1
Other Transportation Equipment**	3.3	4.2	--	--	--
Fabricated Metals	5.8	5.2	3.9	3.3	2.4
Instruments	3.0	4.0	5.4	3.2	5.6
Stone, Clay & Glass	7.3	8.4	3.6	5.1	5.0
Other Durables	4.9	5.0	4.0	3.3	4.9
TOTAL DURABLES	7.0	5.6	5.0	4.2	3.4
Chemicals	10.5	7.7	6.9	7.6	6.6
Paper	13.0	7.9	7.9	6.7	4.9
Rubber	11.8	5.7	4.7	2.8	3.6
Petroleum	8.3	5.4	7.1	4.2	5.1
Food & Beverages	5.2	6.3	3.3	2.7	4.2
Textiles	6.0	7.8	8.8	5.2	4.9
Other Nondurables	5.1	3.0	2.6	2.9	0.8
TOTAL NONDURABLES	8.7	6.2	6.1	5.0	4.8
ALL MANUFACTURING	7.9	5.9	5.6	4.5	4.1
Mining	17.5	10.7	1.6	1.4	5.8
Railroads	1.8	1.6	1.6	3.7	1.9
Airlines	1.7	1.0	2.8	1.9	*
Other Transportation***	2.3	1.8	--	--	--
Electric Utilities	10.6	8.7	10.7	9.2	9.9
Gas Utilities	3.8	1.3	0.7	*	*
Communications & Trade & Services	1.3	1.5	1.3	0.7	0.2
ALL NONMANUFACTURING	4.3	3.3	2.9	2.1	2.2
ALL BUSINESS	5.5	4.2	3.8	3.1	3.0

NA - Not Available

* Less than 0.5%

** Solid waste is included starting in 1975.

*** As of 1979 other transportation equipment is included in other durables and other transportation services are included with communications and commercial.

Environmental Quality-1980

the
eleventh
annual report
of the
council on
environmental
quality

december 1980

Chapter 10

ECONOMICS

The Council estimates that the nation spent approximately $37 billion in 1979 to comply with federal environmental protection requirements—approximately 1.5 percent of the gross national product. It has been suggested that these expenditures may be slowing the growth of productivity. Although studies on the subject are not conclusive, available data suggest that environmental controls have had little impact on productivity.

Regulators have begun to consider economic incentives, including various offset policies which permit one industrial facility to increase air pollution emissions if another facility is willing to reduce them. The purpose of such policies would be to maintain desired levels of environmental quality at a lower overall cost to the nation. The Supreme Court has also begun to consider the issue of costs and benefits in reviewing cases involving environmental regulation.

REGULATION AND PRODUCTIVITY

Between 1948 and 1965, productivity in the United States—measured in terms of dollar value of output in the private sector (corrected for inflation) per hour of paid employment—grew at an average annual rate of approximately 2.5 percent. But in recent years, the rate of productivity growth has slowed substantially. Between 1965 and 1973, the average annual rate of growth was 1.6 percent per year. Between 1973 and 1978, it slowed to 0.8 percent per year.[1] In 1979, for only the second time since World War II, productivity actually fell by 0.9 percent (1974 was the other year). In the first half of 1980, productivity was declining at an annual rate of 1.7 percent. This continuing decline is of concern because increased productivity might make it possible for wages to rise without accompanying price increases. Productivity gains are thus a key element in the effort to control inflation.

Environmental and other forms of regulation are among the many factors that may have slowed productivity growth, but there are others as well. The post-World War II rural-to-urban migration into new jobs in high-productivity manufacturing has ended. Large numbers of unskilled workers have entered the labor force, especially in the cities. Recent increases in energy prices may have encouraged the substitution of labor for energy-intensive capital equipment, and cyclical fluctuations in economic activity may have inhibited investment in new plants and equipment. Finally, there has been a shift in the economy from manufactured goods, which lend themselves to automation and thus increased productivity, to personal and other services, which generally do not.

It is important to determine what effect each of these factors has on productivity. Regulation may reduce productivity—as traditionally measured—if, for example, it diverts labor or capital from the production of goods to the production of safe workplaces or clean air or water.[2] Regulation might also slow productivity growth by delaying the construction of new industrial facilities or requiring their location in areas not convenient to suppliers or transportation lines, thus increasing costs. Similarly, uncertainty about future regulation could adversely affect the development of new and potentially productive technologies.

In any consideration of the relationship between regulation and productivity, however, it is essential to recognize that safe workplaces, clean air and water, unspoiled vistas, reclaimed land, and other benefits of environmental regulation are seldom included in estimates of national productivity. Thus imposition of air or water pollution abatement measures or other regulation will almost always produce a reduction in *measured* output but an increase in unmeasured benefits. Although reductions in productivity because of stagnation or decline in measured output are always of concern, they are acceptable if the unmeasured benefits of regulation are of greater value to society than those that are lost.[3] To the extent that this shift from measured to unmeasured output is responsible for declining productivity growth, the "problem" is only an artifact of our current measurement system.

In the past several years, economists have tried to determine statistically the individual contributions of the many factors that affect the rate of productivity growth, as traditionally measured. The first attempt to quantify the impact of environmental regulation on productivity growth appeared in 1978.[4] Using estimates of annual nonresidential business expenditures on pollution abatement (much like those presented later in this chapter), the study tried to determine the probable increase in productivity had the labor and capital used for pollution control been used for normal production instead. In its calculations, the study assumed that all resources devoted to pollution control would have been used for production and that those resources were of average productivity.

The study found that between 1967 and 1969, pollution abatement expenditures reduced the annual rate of growth of productivity

0.05 percent. Between 1969 and 1973, the effect was estimated at 0.10 percent, and between 1973 and 1975, 0.22 percent, i.e., the annual rate for 1975 would have been 0.822 rather than 0.080. The difference may seem small, but the size of the national income makes the absolute dollar amounts of output foregone substantial.

Both of the study's underlying assumptions are open to question, however. First, it is unlikely that all the money used for pollution control from 1967 to 1975 would have been spent on conventional production. Two of those years were recession years during which additional output would have been difficult to sell. Assuming a dollar-for-dollar displacement, then, probably leads to overestimation of the impact of regulation on productivity. Second, in general, the most productive resources are utilized first, the least productive, last. Thus if environmental regulation requires the diversion of existing labor and capital or the addition of new resources, the resources diverted are likely to be less productive than those devoted to the continued production of conventional output. In this respect also, it is likely that the study overestimated the adverse effects of regulation. These tendencies toward overestimation are offset to some extent by the fact that the study ignored the indirect, and perhaps significant, effects of regulation on productivity growth resulting from delay and siting effects, for example. It is thus difficult to draw definitive conclusions about the overall effects of regulation on productivity growth from this study.

The author of this study recently applied this same approach to more recent data on pollution abatement expenditures and data then available on GNP.[5] He calculated that between 1975 and 1978, expenditures on air and water pollution control and solid waste disposal reduced the rate of productivity growth 0.08 percent—about one-third the effect that these controls were thought to have had beween 1973 and 1975. The later calculations suggest that, although environmental regulation was still adversely affecting the rate of productivity growth in the late 1970s, as conventionally measured, its impact appears to be diminishing.

Numerous studies have attempted to quantify the effects of various factors on the slowdown in productivity growth.[6] These reviews suggest that some of the factors mentioned above may play larger roles in the decline in productivity growth than does environmental regulation. One review of the studies concluded that "in no case are pollution abatement regulations assigned more than 20 percent [or about 0.2–0.4 percent] of the responsibility for the decrease in productivity growth. The typical estimate of the role of environmental regulations is in the range of 5–15 percent [about 0.05–0.3 percent]."[7]

ECONOMIC INCENTIVES

Economic incentives may be effective in controlling pollution.[8] Possible incentives might be effluent charges (fees that must be paid for each unit of pollution discharged) or marketable permits (legally enforceable entitlements to discharge that are fixed in number and exchangeable among polluters). Under certain conditions, both effluent charges and marketable permits are considered capable of vastly reducing the cost of improving environmental quality by taking advantage of variations in the costs of pollution control among dischargers—variations determined for the most part by the kind of raw material and process involved.

The Environmental Protection Agency's bubble and offset policies (the former allows a polluter to increase air emissions in one portion of a facility if it will reduce emissions elsewhere in the same facility, where costs may be lower; the latter permits an increase in emissions in one part of a geographic area if the polluter either reduces pollution elsewhere in that area or persuades another polluter to do so) are attempts to make use of economic incentives within the current regulatory framework.[9]

EPA is also considering several other incentive-based approaches. Transferable Emissions Reduction Assessments (TERAs) might be used if the emission controls required under State Implementation Plans (SIPs) were insufficient to meet the ambient air quality standards established under the Clean Air Act. Normally, the long process of a SIP revision would be necessary in such circumstances. Under the TERA approach, if a 10 percent reduction in overall emissions were required to meet the standards in a particular area, every pollution source in that region would be directed to cut its emissions 10 percent. But if one source could find another comparable source in the area able to reduce its emissions at a reasonable cost and then persuade that source to cut back 20 percent (in exchange, say, for financial considerations), the first source could avoid a cutback. In other words, firms could either make the reductions themselves or find offsetting reductions elsewhere. Such a procedure could have a cost-saving advantage and speed up the process of environmental improvement.

EPA is considering other incentive-based approaches to prevent significant deterioration (PSD) in areas where air quality is better than national standards. The Clean Air Act limits the extent to which air quality can be diminished in such areas. EPA must determine which sources may "consume" the incremental degradation that is permitted. This increment could be allocated on a first-come, first-served basis as sources apply for new permits. But other systems of allocation could also be used:

- Variable offsets—a potential new source could purchase some emissions entitlements from existing sources but less than it expects to emit (because some degradation is permitted)
- Emission density zoning—emissions entitlements would first be limited and then tied to particular parcels of land in PSD areas
- Emissions fees—potential sources would pay for the additional

degradation that they cause, and the price would rise as air quality approached the minimum permitted quality.

All three methods of allocating allowable increases in degradation are based on differences in the costs of pollution control among sources.

The Clean Air Act distinguishes between new and existing sources of pollution. In general, new sources are held to much stricter performance standards (new source performance standards, NSPS) than existing ones on the premise that environmental quality will gradually improve as existing sources are retired; in time, all sources will be subject to strict controls. Critics of this approach argue that it may unintentionally result in old plants being operated long past the point at which they would otherwise have been retired in order to avoid the strict controls on new sources.[10] There is little evidence available on the extent to which new plant construction is being delayed, but it may be worth thinking about ways to secure the same reductions in emissions that would result from strict NSPS without discouraging new plant construction.

One way to achieve this goal would be to allow new sources of pollution to operate under less stringent controls than those now required if they can secure equal or perhaps even greater than offsetting reductions from other new or existing sources in the same geographical area. Pollution would then be reduced by the same amount as under the NSPS approach, but some of the disincentive to introduce new sources would be removed. In some cases, securing emission reductions from existing sources (which are often largely uncontrolled) would be less costly than the higher removal efficiencies called for under existing new source performance standards.

An additional benefit of using the offset approach in the NSPS might be improved productivity secured by use of more sophisticated technology in new plants and equipment that allow each worker to produce more than before. Thus environmental quality might be maintained without loss of productivity.

Another and different kind of economic incentive might increase the accuracy of the information that polluters provide to regulatory agencies in advance of standard setting. When EPA is considering imposition of a standard, it needs to know the cost to a company of meeting that standard. Under current practice, the company has an incentive to exaggerate the cost to make the regulation appear unjustifiable (some evidence of the accuracy of both private and government estimates of compliance costs is discussed later in this chapter). If in fact companies are exaggerating compliance costs, they are depriving regulatory agencies of potentially the most reliable cost data, that from the affected firms.

What can be done to prevent exaggeration of expected compliance costs? One possibility is to link penalties for violations to compliance cost estimates—that is, to make the penalty for noncompliance with an established regulation dependent upon the previous estimate of the costs of compliance. Then a company would be free to claim that compliance with a proposed regulation would be unjustifiably costly, but future penalties for noncompliance would be greater than if the firm had provided a more realistic estimate of costs.

Linking noncompliance penalties to compliance cost estimates might make it possible to improve *ex ante* analysis (analysis prior to issuance of regulations) of the impacts of regulation by providing more accurate information than is now available. For such a system to have legal sanction, the affected firms would have to make their cost estimates official, increasing the resources needed to estimate costs, resources otherwise available for production. The usefulness of such an approach, then, depends upon the value of improved estimates of compliance costs compared to the additional effort entailed by such estimates.

Still another means of obtaining more accurate information on the costs of complying with environmental regulation is suggested by recent action taken by the Securities and Exchange Commission. The SEC ordered two very large firms—U.S. Steel and Occidental Petroleum—to disclose to their stockholders potential liabilities arising from pollution control costs or other environmental activities.[11] The SEC found that between 1973 and 1977, U.S. Steel had not adequately disclosed to its stockholders the costs associated with coming expenditures on air and water pollution control, thus making its financial condition appear better than was actually the case. Occidental, the SEC found, had failed to inform stockholders of possible liabilities arising from waste disposal practices of its subsidiary, Hooker Chemical, at Love Canal.

If firms were required to incorporate in reports to the SEC and to report to stockholders the same estimates of pollution control compliance costs that they provide to regulatory agencies, exaggerated estimates to agencies might become less common. Presumably, firms would not want to alarm stockholders with the prospect of large liabilities for pollution control. Neither would they want regulatory agencies to think that potential new regulations were costless.

COST-BENEFIT ANALYSIS AND THE COURTS

Unsettled issues in the setting of regulations include the extent to which regulatory agencies must demonstrate the benefits of their proposed actions and the relationship that these benefits must bear to the costs of regulation. The Supreme Court considered in part the first of these issues in 1980.

In July 1980, the Supreme Court handed down a decision in *Industrial Union Department, AFL–CIO* v. *American Petroleum Institute et al.*[12] The Court upheld in part a 1978 ruling by the U.S. Court of Appeals for the Fifth Circuit.[13] The Fifth Circuit had ruled in favor of the American Petroleum Institute (API) that the Occupational Safety and Health Administration (OSHA) could not tighten the standard limiting worker exposure to benzene from 10 parts per million to 1 ppm without first conducting a cost-benefit analysis of the proposed change. OSHA had argued that some of the costs and benefits of the proposed change were unquantifiable and that it was prohibited by law from considering the costs of regulation except to determine that industry was capable of bearing them.

By a 5–4 majority, the Supreme Court upheld the circuit court's invalidation of the benzene standard on grounds that OSHA had failed to produce evidence that a "significant risk of harm exists" at the old standard that would justify the proposed revision. Rather, OSHA had merely asserted that the change would afford workers more protection.

The Court chose not to rule on whether benefits had to be completely and precisely quantified or had to bear some reasonable relationship to costs.[14]

EXPENDITURES ON ENVIRONMENTAL QUALITY

Each year the Council has estimated current and future expenditures for pollution abatement and other measures to protect or enhance environmental quality. These estimates serve several purposes. They can be used to help determine the macroeconomic effects of federal environmental regulation,[15] and they can be compared with broad-scale estimates of the benefits associated with environmental regulations.[16] Because of their high level of aggregation, however, the CEQ estimates cannot be used to evaluate the benefits and costs of specific standards or provisions of the Clean Air Act, the Clean Water Act, or similar legislation. Such evaluations are clearly of great importance when changes are considered in specific provisions of environmental statutes.

As Table 10–1 indicates, CEQ estimates that the nation spent $36.9 billion in 1979 to comply with federal environmental protection regulations. (Spending necessitated by federal regulation is termed "incremental" by CEQ). The $36.9 billion amounted to approximately 1.5 percent of GNP in 1979, 0.2 percent higher than in past years. The increase was caused by spending on new regulations, the effects of which are only now beginning to be felt. The Toxic Substances Control Act and the Surface Mining Control and Reclamation Act are the most prominent examples.

Air and water pollution controls (mandated by the Clean Air Act and Clean Water Act) accounted for 95 percent of incremental expenditures, $35.0 billion. Of this amount, air pollution control accounted for $22.3 billion—$1.5 billion of which was spent by federal, state, and local governments for the control of air pollution at hospitals, military installations, incinerators, and other municipal disposal

Table 10–1

Estimated Incremental Pollution Abatement Expenditures,[a] 1979–88

(billions of 1979 dollars)

	1979			1988			Cumulative (1979–88)		
Program	Operation and maintenance	Annual capital costs [b]	Total annual costs	Operation and maintenance	Annual capital costs [b]	Total annual costs	Operation and maintenance	Capital costs [b]	Total costs
Air pollution									
Public	1.2	.3	1.5	2.0	.5	2.5	15.8	3.7	19.5
Private									
Mobile	3.2	4.9	8.1	3.7	11.0	14.7	32.1	83.7	115.8
Industrial	2.0	2.3	4.3	3.0	4.1	7.1	25.8	33.0	58.8
Electric utilities	5.5	2.9	8.4	7.6	5.7	13.3	62.3	42.7	105.0
Subtotal	11.9	10.4	22.3	16.3	21.3	37.6	136.0	163.1	299.1
Water Pollution									
Public	1.7	4.3	6.0	3.3	10.0	13.3	25.1	59.2	84.3
Private									
Industrial	3.4	2.6	6.0	5.4	4.5	9.9	42.0	34.0	76.0
Electric utilities	.3	.4	.7	.3	.9	1.2	2.9	6.5	9.4
Subtotal	5.4	7.3	12.7	9.0	15.4	24.4	70.0	99.7	169.7
Solid waste									
Public	<.05	<.05	<.05	.4	.3	.7	2.6	2.0	4.6
Private	<.05	<.05	<.05	.9	.7	1.6	6.4	4.4	10.8
Subtotal	<.05	<.05	<.05	1.3	1.0	2.3	9.0	6.4	15.4
Toxic substances	.1	.2	.3	.5	.6	1.1	3.6	4.6	8.2
Drinking water	<.05	<.05	<.05	.1	.3	.4	1.3	1.4	2.7
Noise	<.05	.1	.1	.6	1.0	1.6	2.6	4.3	6.9
Pesticides	.1	<.05	.1	.1	<.05	.1	1.2	<.05	1.2
Land reclamation	.3	1.1	1.4	.3	1.2	1.5	3.8	11.5	15.3
Total	17.8	19.1	36.9	28.2	40.8	69.0	227.5	291.0	518.5

[a] Incremental costs are those made in response to federal legislation beyond those that would have been made in the absence of that legislation.

[b] Interest and depreciation.

sites. The control of air pollution from automobiles, trucks, buses, and motorcycles cost $8.1 billion. Electric utilities spent $8.4 billion for air pollution control; all other industrial sources spent $4.3 billion. The $22.3 billion for air pollution control was divided rather evenly between operation and maintenance expenses and annual capital costs (which include interest and depreciation).

Of the $12.7 billion in incremental water pollution control expenditures in 1979, municipalities spent $6.0 billion for waste water treatment. Industrial sources other than electric utilities spent another $6.0 billion for water pollution control; utilities accounted for the remaining $0.7 billion.

Approximately $1.9 billion spent in 1979 was expended on the reclamation of land following strip mining (under the Surface Mining Control and Reclamation Act), the control of toxic substances (under the Toxic Substances Control Act), the protection of drinking water (under the Safe Drinking Water Act), the elimination or attenuation of noise (under the Noise Control Act), and the control of pesticides (under the Federal Insecticide, Fungicide, and Rodenticide Act). Land reclamation accounted for $1.4 billion of the $1.9 billion devoted to expenditures on other than air and water pollution control.

CEQ estimates that by 1988, expenditures necessitated by federal environmental measures will grow to $69.0 billion (in 1979 dollars), a real rate of growth of about 7.2 percent per year. Air and water pollution control will still account for the greatest share of incremental spending in 1988—$62.0 billion—but spending for other programs will grow to 10 percent of the total. By then, $2.3 billion will be required annually to control the disposal of hazardous and other wastes in compliance with the Resource Conservation and Recovery Act.

During the 10 years 1979–88, spending in response to the federal environmental quality regulations considered here is expected to amount to $518.5 billion. Of this cumulative incremental spending, air pollution control will total nearly $300 billion (58 percent), water quality programs will require about $170 billion (33 percent), and all other programs together will account for the remaining $50 billion. Of this $50 billion, $15.3 billion will be devoted to land reclamation and another $15.4 billion to control of the disposal of hazardous wastes. The control of hazardous substances will require $8.2 billion, and noise control measures will cost $6.9 billion.

In addition to estimating spending in response to federal environmental legislation, CEQ has estimated total spending on pollution abatement and other environmental measures, including expenditures made in response to state or local environmental controls (which are sometimes quite stringent) or voluntary expenditures made for reasons of principle or private profitability. These estimates obviously require some assumptions about what industry, households, and government units would have spent on pollution control in the absence of federal regulations. These baseline expenditures, as they are called, are determined by examining environmental expenditures in the mid- to late 1960s prior to establishment of present federal environmental regulations and then extrapolating trends to the present. Because extrapolation of this kind is a particularly difficult task, estimates of total expenditures should be viewed as only broadly suggestive.

As shown in Table 10–2, spending on all environmental programs, either voluntary or in response to federal, state, or local statutes, is estimated at $735.0 billion between 1979 and 1988. Air pollution will account for $338.8 billion, water pollution for $250.0 billion, and solid waste disposal for $100.9 billion. The share of solid wastes in total expenditures is much greater than its share in incremental spending because much of the spending on solid wastes is either voluntary or in response to state or local regulations. All other programs are expected to account for $45.3 billion of total expenditures between 1979 and 1988.

There is a great deal of uncertainty in these estimates. Although they are presented as point estimates (that is, as single numbers), they might better be presented as ranges because of the uncertainties involved in determining them. It should also be noted that these estimates reflect anticipated costs of compliance for environmental regulations in effect as of mid-1980. This year's totals reflect new methods for estimating compliance costs for several programs. Differences in methods explain some differences between this year's estimates and those in previous Annual Reports.

ACCURACY OF POLLUTION CONTROL COST ESTIMATES

A study conducted for EPA in 1980 attempted to assess the accuracy of some of the estimated costs of complying with federal environmental law.[17] Because the study did not consider all industries and regulations or the cost of regulation to the public, its findings cannot easily be generalized to the aggregate estimates of federal environmental regulation compliance costs that CEQ makes. Nevertheless, the report gives some indication of the precision of compliance cost estimates.

The study compared *ex ante* estimates of pollution control costs for several industries made when a regulation was issued with actual expenditures that were eventually made. It examined estimates prepared by EPA and its contractors and estimates prepared by industry. Estimates were then adjusted for the fact that not all firms actually complied with the regulations; "compliance-adjusted" estimates were compared with actual expenditures.

The study examined estimates of compliance costs of best practicable technology (BPT) effluent guidelines for the iron and steel, pulp and paper, petroleum refining, and steam electric utility industries

Table 10–2

Estimated Total Pollution Abatement Expenditures, 1979–88

(billions of 1979 dollars)

Program	1979			1988			Cumulative (1979–88)		
	Operation and maintenance	Annual capital costs	Total annual costs	Operation and maintenance	Annual capital Costs[a]	Total annual costs	Operation and maintenance	Capital costs	Total costs
Air pollution									
Public	1.7	.4	2.1	2.8	.7	3.5	22.5	5.3	27.8
Private									
Mobile	3.2	4.9	8.1	3.7	11.0	14.7	32.1	83.7	115.8
Industrial	2.5	2.9	5.4	3.9	5.1	9.0	32.5	41.5	74.0
Electric utilities	6.3	3.5	9.8	8.5	6.5	15.0	71.1	50.1	121.2
Subtotal	13.7	11.7	25.4	18.9	23.3	42.2	158.2	180.6	338.8
Water pollution									
Public	3.7	8.2	11.9	5.4	14.2	19.6	45.4	99.7	145.1
Private									
Industrial	4.4	3.2	7.6	6.4	5.1	11.5	52.4	41.1	93.5
Electric utilities	.4	.5	.9	.4	1.1	1.5	3.6	7.8	11.4
Subtotal	8.5	11.9	20.4	12.2	20.4	32.6	101.4	148.6	250.0
Solid waste									
Public	1.7	.3	2.0	2.5	.6	3.1	21.8	5.3	27.1
Private	4.5	.7	5.2	7.5	1.6	9.1	61.3	12.5	73.8
Subtotal	6.2	1.0	7.2	10.0	2.2	12.2	83.1	17.8	100.9
Toxic substances	.1	.2	.3	.5	.6	1.1	3.6	4.6	8.2
Drinking water	.3	.4	.7	.5	.8	1.3	5.3	5.2	10.5
Noise	<.05	.1	.1	.6	1.0	1.6	2.6	4.3	6.9
Pesticides	.1	<.05	.1	.1	<.05	.1	1.6	.1	1.7
Land reclamation	.4	1.3	1.7	.4	1.4	1.8	4.5	13.5	18.0
Total	29.3	26.6	55.9	43.2	49.7	92.9	360.3	374.7	735.0

[a] Interest and depreciation.

issued under the Clean Water Act, Clean Air Act requirements for scrubbers in the electric utility industry, and vehicle emissions standards for new light-duty automobiles required by the Clean Air Act.

The study report reveals that compliance cost estimates prepared by EPA or its contractors were lower than industry estimates for five of the six regulations examined; only the pulp and paper industry's estimate of the costs of meeting BPT effluent guidelines was below that of EPA. However, EPA estimates were not consistently high or low compared to actual costs. In two cases EPA appeared to underestimate costs, in three cases it appeared to overestimate costs, and for vehicle emissions standards, the estimates appeared to be too high in two model years and too low in a third.

Industry also overestimated compliance costs in some cases and underestimated in others. For the BPT guidelines in the iron and steel industry, the apparent overestimate was substantial, ranging from 2.5 to 3.5 times the actual cost. On the other hand, industry estimates of the cost of scrubbers to electric utilities and the cost of the BPT effluent guidelines in the pulp and paper industry were less than actual expenditures. Industry compliance cost estimates for vehicle emissions standards were both higher and lower than actual increases in sale prices resulting from the regulations.

Overall, the report shows that EPA appears to be slightly better at estimating compliance costs than are the affected industries. As Table 10–3 indicates, EPA's ratio of estimated-to-actual expenditures is more often nearer 1.0 than the ratio for corresponding industry estimates (a ratio of 1.0 means that actual expenditures were forecast exactly). In BPT guidelines for electric utilities and model year 1976 vehicle emissions costs, the EPA estimate was within 10 percent of eventual actual expenditures. The electric utility industry's estimate of scrubber costs was also within 10 percent of actual expenditures.

A first attempt to compare predicted and actual compliance costs, this study is a useful one. But it must be interpreted carefully. First, it is difficult to determine actual (*ex post*) expenditures incurred to comply with a regulation. The study used data reported by the Bureau of Economic Analysis, McGraw-Hill, the Bureau of Labor Statistics, and industry trade associations. Although these data are the best available on actual spending for pollution control, they do not differentiate between spending undertaken to comply with specific federal regulations and that undertaken because of state or local regulations or private profitability. Further, it is difficult to isolate pollution control spending from that for modern equipment and streamlined production processes, for example.

In addition, as Chapter 4, Air Quality, points out, compliance data vary in quality. Thus it is not clear how accurate estimates of pollution control compliance costs are once they have been adjusted for industry compliance ratios. Such an adjustment will not affect the

Table 10–3

Ratio of Estimated to Actual Pollution Control Expenditures in Selected Industries

Industry and regulation	Ratio
Electric utility scrubber	
EPA	0.74
Industry	0.91
Utilities (BPT guidelines)	
EPA	0.89–0.91
Industry	1.36–1.40
Pulp and paper (BPT guidelines)[a]	
EPA	1.27–1.49
Industry	0.75
Iron and steel (BPT guidelines)	
EPA	1.32–1.79
Industry	2.56–3.47
Petroleum refining (BPT guidelines)	
EPA	1.87–2.50
Industry	1.91–2.62
Automobile emissions standards[b]	
1974 model year	
EPA	1.32–1.45
Industry	0.72–1.74
1976 model year	
EPA	0.93–1.02
Industry	0.51–2.31

BPT = Best practicable technology.

[a] EPA estimate, 1974–77; industry estimate, 1972–77.

[b] Ratio of estimated to actual sale price increase as calculated by the Bureau of Labor Statistics.

Source: Putnam, Hayes & Bartlett, Inc., "Comparisons of Estimated and Actual Pollution Control Cost for Selected Industries," prepared for the U.S. Environmental Protection Agency, February 1980.

accuracy of EPA estimates compared with those of industry (because both are adjusted in the same way). But the tendency of either party to over- or under-estimate actual costs is less apparent.

REFERENCES

1. See Council of Economic Advisors, *Economic Report of the President* (Washington, D.C.: U.S. Government Printing Office, 1980), p. 85.
2. See Council on Environmental Quality, *Environmental Quality—1979: The Tenth Annual Report of the Council on Environmental Quality* (Washington, D.C.: U.S. Government Printing Office, 1980), pp. 647–48.
3. For a comprehensive analysis of the benefits of air and water pollution control, see A.M. Freeman, *The Benefits of Air and Water Pollution Control: A Review and Synthesis of Recent Estimates* (Springfield, Va.: National Technical Information Service, 1980).
4. Edward Denison, "Effects of Selected Changes in the Institutional and Human Environment upon Output per Unit Input," *Survey of Current Business* 58(1):21–44 (1978).

5. Edward Denison, "Pollution Abatement Programs: Estimates of Their Effect upon Output per Unit Input," *Survey of Current Business* 59(8):58–59 (1979).
6. See Gregory Christainsen and Robert Haveman, University of Wisconsin-Madison, "Environmental Policy and the Slowdown in U.S. Productivity Growth: An Assessment of the Evidence," prepared for the Environmental Directorate, Organization for Economic Cooperation and Development, September 1979; Gregory Christainsen and Robert Haveman, University of Wisconsin-Madison, "Environmental Regulation and Its Impact on the Economy," prepared for Resources for the Future, April 1980.
7. Gregory Christainsen and Robert Haveman, "Environmental Regulation and Its Impact on the Economy," *supra* note 6, at 38.
8. See, for example, Council on Environmental Quality, *supra* note 2, at 668–80.
9. For an explanation of these policies, see *id.* pp. 678–80.
10. For one such view, see ICF, Inc., "Effects of Alternative New Source Performance Standards for New Coal-Fired Electric Utility Boilers on the Coal Market and on Utility Capacity Expansion Plans," submitted to the U.S. Environmental Protection Agency and the U.S. Department of Energy, September 1978, p. 11.
11. See Agis Salpukas, "U.S. Steel Disclosure Criticized," *Wall Street Journal*, September 28, 1979; John F. Berry, "Occidental Told to List Liabilities," *Washington Post*, July 3, 1980, p. E1.
12. *Industrial Union Department, AFL-CIO* v. *American Petroleum Institute et al.*, No. 78–911, and *Ray Marshall, Secretary of Labor* v. *American Petroleum Institute et al.*, No. 78–1036 (S. Ct. July 2, 1980).
13. *American Petroleum Institute* v. *Occupational Safety and Health Administration*, 581 F.2d 493 (5th Cir. 1978).
14. See *Industrial Union Department, AFL-CIO*, *supra* note 12.
15. For example, see Data Resources, Inc., "The Macroeconomic Impact of Federal Pollution Control Programs: 1978 Assessment" (Springfield, Va.: National Technical Information Service, 1979).
16. See A.M. Freeman, *supra* note 3.
17. Putnam, Hayes & Bartlett, Inc., "Comparisons of Estimated and Actual Pollution Control Cost for Selected Industries," prepared for the U.S. Environmental Protection Agency, February 1980.

96TH CONGRESS } SENATE { DOCUMENT
1st Session } { No. 96–38

THE COST OF CLEAN AIR AND CLEAN WATER

ANNUAL REPORT

OF THE

ADMINISTRATOR OF THE ENVIRONMENTAL
PROTECTION AGENCY

TO THE

CONGRESS OF THE UNITED STATES

IN COMPLIANCE WITH

SECTION 312(c) OF THE CLEAN AIR ACT, AS AMENDED

AND

SECTION 516(b) OF THE FEDERAL WATER POLLUTION
CONTROL ACT AMENDMENTS OF 1972

DECEMBER 1979

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON : 1979

COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

JENNINGS RANDOLPH, West Virginia, *Chairman*

EDMUND S. MUSKIE, Maine	ROBERT T. STAFFORD, Vermont
MIKE GRAVEL, Alaska	HOWARD H. BAKER, Jr., Tennessee
LLOYD M. BENTSEN, Texas	PETE V. DOMENICI, New Mexico
QUENTIN N. BURDICK, North Dakota	JOHN H. CHAFEE, Rhode Island
JOHN C. CULVER, Iowa	ALAN K. SIMPSON, Wyoming
GARY HART, Colorado	LARRY PRESSLER, South Dakota
DANIEL PATRICK MOYNIHAN, New York	

JOHN W. YAGO, Jr., *Staff Director*
BAILEY GUARD, *Minority Staff Director*

(II)

SENATE RESOLUTION

Submitted by Mr. Randolph of West Virginia

S. Res. 266

96TH CONGRESS
1ST SESSION

S. RES. 266

[Report No. 96-439]

Authorizing the printing of the report entitled "The Cost of Clean Air and Water" as a Senate document.

IN THE SENATE OF THE UNITED STATES

OCTOBER 29 (legislative day, OCTOBER 15), 1979

Mr. RANDOLPH, from the Committee on Environment and Public Works, reported the following resolution; which was referred to the Committee on Rules and Administration

NOVEMBER 30 (legislative day, NOVEMBER 29), 1979
Reported by Mr. PELL, without amendment

DECEMBER 6 (legislative day, NOVEMBER 29), 1979
Considered and agreed to

RESOLUTION

Authorizing the printing of the report entitled "The Cost of Clean Air and Water" as a Senate document.

Resolved, That the annual report of the Administrator of the Environmental Protection Agency to the Congress of the United States in compliance with section 312(c) of the Clean Air Act, as amended, and section 516(b) of the Federal Water Pollution Control Act Amendments of 1972 entitled, "The Cost of Clean Air and Water" be printed, with illustrations, as a Senate document.

SEC. 2. There shall be printed five hundred additional copies of such document for the use of the Committee on Environment and Public Works.

EXECUTIVE SUMMARY

This report to Congress is mandated by the Clean Air and Water Acts. In both Acts, the Administrator of the Environmental Protection Agency is directed to make and report detailed estimates of the costs of carrying out the respective Acts. This report presents such estimates as two separate reports, one concerned with the control of air pollution, the other with the control of water pollution. This summary provides information on both reports and presents listings of "water costs", "air costs", and "combined costs".

The estimates reported here are limited to costs associated with Federal regulatory actions resulting from the Clean Air and Clean Water Acts, and do not account for costs voluntarily incurred by pollutors, required by State or local governments only, or mandated by other Federal laws. The estimates given here do not include costs incurred prior to the dates of the respective Acts (Air—1970, Water—1972), nor is any estimate given of the expenditures which would have taken place if the Acts had not been passed.

It should be noted that this document specifically does not dictate EPA policy with regard to the application of presently available or projected emissions-control technology to any industry or activity. Simplifying assumptions were required in order to estimate the cost of complying with EPA regulations on the source industries included herein. Thus, the control technologies assumed in providing these estimates are not to be regarded as specifically required by law nor by EPA. Moreover, the reader is cautioned that costs estimated in this study may differ from costs estimated in other studies because of differences in definition of the industries.

The costs reported for the control of air pollution are, for the most part, based on compliance with Federally-approved State Implementation Plans, Federal New Source Performance Standards, and Federal regulations for mobile sources. The costs reported for the control of water pollution are, for the most part, based on compliance with Federal Effluent Limitations Guidelines, New Source Performance Standards, and Pretreatment Standards. Regulations on hazardous and toxic pollutants are also taken into account.

This report was prepared in 1978, and reflects the regulatory framework in existence early in 1978. Projections beyond past expenditures are subject to change for both air and water. The Clean Air Act Amendments of 1977 contain significant changes that will affect future costs. The Clean Water Act of 1977, amending the Federal Water Pollution Control Act of 1972, also contains significant changes that will affect the future regulatory picture and the associated cost to industry.

In the case of air, some additional costs can be expected to comply with the revised State Implementation Plans and the provisions of Prevention of Significant Deterioration and Visibility Goals.

The reported projections for water pollution control costs are more difficult to assess. The Clean Water Act of 1977 will require less stringent controls for conventional pollutants. However, the 1976 Consent Agreement may result in more stringent guidelines for the 21 industries covered by the agreement.

The magnitude of these changes will vary considerably on an industry-by-industry basis. An extreme example is the Explosives industry. The Cost of Clean Water estimates show slightly over $2 billion of investment from 1977–1986. Preliminary estimates emanating from the current BAT-review process indicate that new investment will only be about $3–4 million for this industry. While this is not representative of the magnitude of the changes to be expected, it does indicate the degree of uncertainty in the present estimates. *Therefore, the reader should keep in mind that the costs presented here represent only what industries would have had to pay if the regulations in effect in early 1978 remained unchanged.*

COST OF IMPLEMENTING THE ACTS

In the presentation of costs, 1977 is the base year; all costs are expressed in millions of 1977 dollars. Investment and annual costs are reported for two historical periods: 1970—77 (Air), 1972—77 (Water) and are projected for the period from 1977 through 1986.

The costs reported include:

- Capital costs of equipment and installation
- Capital recovery (depreciation) and interest on unrecovered capital
- Direct operating and maintenance costs.

The methodology used to generate costs is discussed in the introduction of each report and in more detail in the specific chapters. The methodology involves the analysis of specific regulations, in terms of affected sectors of industry, and the costing of control equipment or methods characteristic to each sector.

The costs are the result of engineering estimates; they are not obtained from industry surveys. The estimates are based on the assumed application of existing technology, and are developed by various techniques such as the use of "model" plants, or actual data on an existing plant. Various other assumptions are used, such as the utilization of an "average" air-pollution regulation typical of all State Implementation Plans. The assumptions used are judged to result in an overstatement of costs, since no allowances are made for in-process changes or technological innovation, either of which might reduce the costs of pollution control.

The findings are presented in condensed form in the three following tables. Table 1 presents estimated total air and water pollution control costs, Table 2 shows estimated air pollution control costs, and Table 3 indicates estimated water pollution control costs. The tables show both investment costs and annualized costs.

Major industry groups are consistent in the tables; however, individual line items are presented only where costs have been developed. Some industries have only air or only water costs associated with them and so appear in only one of the last two tables. Table 1 is the sum of Tables #2 and 3. For example, the table entry for Mobile Sources appears in Tables 1 and 2 as an air pollution item. A key to accessing the way individual industry chapters were used to combine the two air and water reports is given as a note at the end of this Summary.

The costs to government shown in the tables are based on expenditures to run programs at the Federal, State, and local levels and the projected distribution of grants for construction of municipal water treatment plants. Program operating costs are shown for both air and water pollution control in terms of "Annual Costs" in both Table 2 and 3; the construction grants are shown as "Investment" in Table 3, with annualized capital costs of the grants included in the "Annual Costs" shown in Table 3.

Various major industries appear as single entries because of their significance in terms of pollution control costs, such as electric utilities, petroleum refining, iron and steel, primary aluminum and copper, and pulp and paper. The *Mobile Sources* category includes passenger cars, light and heavy-duty gasoline and diesel trucks, aircraft, and motorcycles. The category of *Other Food Processing* includes grain handling, feed mills, sugar processing, canning and preserving of fruits and vegetables and seafood, and processing of dairy products. The *Basic Inorganic Chemicals* group includes sulfuric acid and chlor-alkali production; the *Organic Chemicals* category includes production of petrochemicals, organic chemicals, plastics and synthetics, and vinyl chloride; the *Agricultural Chemicals* category includes production of fertilizers, pesticides, nitric acid, and other products based on phosphate rock and phosphorus; the *Formulated Chemicals* group includes the production of paints, inks, carbon black, soaps, detergents, explosives, gum and wood chemicals, and pharmaceuticals. The *Construction Materials* group includes activities such

TABLE 1. COST OF AIR AND WATER POLLUTION CONTROL
(IN MILLIONS OF 1977 DOLLARS)

			INVESTMENT	
	1977	1970–77	1977–81	1977–86
COSTS TO GOVERNMENT	5065.00	21593.00	19677.00	45882.00
FUELS & ENERGY				
COAL MINING & COAL CLEANING	22.13	128.73	16.25	30.34
OIL & GAS EXTRACTION & PROCESSING	563.95	912.26	383.18	779.43
PETROLEUM REFINING	902.91	3321.15	1062.52	1326.76
ELECTRIC UTILITIES	3877.70	13127.70	11051.73	20913.55
COAL GASIFICATION	0.0	0.0	70.44	412.03
SUBTOTAL	5366.69	17489.84	12584.12	23462.11
MOBILE SOURCES	2912.00	12050.09	17234.55	49051.55
FOOD PROCESSING				
FEEDLOTS & MEAT PROCESSING	36.52	122.74	159.82	241.12
OTHER FOOD PROCESSING	689.60	4153.08	991.06	2116.23
SUBTOTAL	726.12	4275.82	1150.88	2357.35
CHEMICALS				
BASIC INORGANIC CHEMICALS	254.33	989.21	524.83	875.01
ORGANIC CHEMICALS	1009.65	2060.90	1449.64	2947.17
AGRICULTURAL CHEMICALS	125.24	270.10	152.87	276.04
FORMULATED CHEMICALS	258.38	711.21	1357.15	2129.50
SUBTOTAL	1547.61	4031.41	3484.49	6227.71
CONSTRUCTION MATERIALS	101.70	677.90	198.47	312.25
METALS				
ORE MINING & DRESSING	152.50	389.59	251.00	251.00
IRON & STEEL	981.22	2668.26	2337.60	3613.98
ALUMINUM	71.34	400.35	147.07	410.12
COPPER	90.00	1094.00	171.70	986.00
NONFERROUS METALS, FERROALLOYS, & FOUNDRIES	69.42	731.88	63.05	15091
SUBTOTAL	1364.49	5284.08	2970.42	5412.01
SOFTGOODS				
PULP & PAPER	964.00	3099.75	870.75	1953.05
TEXTILES	24.21	87.84	1030.71	1410.16
LEATHER & RUBBER	82.93	198.40	121.20	181.72
SUBTOTAL	1071.13	3385.99	2022.16	3544.92
MANUFACTURING				
ELECTROPLATING	49.79	264.74	81.55	81.55
SURFACE COATINGS	0.0	0.0	658.32	1707.64
FURNITURE MANUFACTURING	0.0	0.0	2.80	4.80
SUBTOTAL	49.79	264.74	743.17	1793.99
SERVICES				
DRYCLEANING	10.04	141.75	6.75	13.27
HOSPITALS	24.50	69.77	25.65	69.56
PHOTOGRAPHIC PROCESSING	6.21	14.47	5.59	15.69
SUBTOTAL	40.75	225.99	38.00	98.53
WASTE DISPOSAL				
OPEN DUMPS & OPEN BURNING	145.33	1744.12	718.62	2023.34
MUNICIPAL WASTE INCINERATION	4.29	27.11	11.31	24.72
SUBTOTAL	149.62	1771.23	729.93	2048.06
OTHER INDUSTRIAL COSTS				
INDUSTRIAL & COMMERCIAL HEATING BOILERS	238.11	1970.21	268.26	465.11
INDUSTRIAL, COMMERCIAL & BLDG. INCINERATORS	57.02	256.61	275.62	693.80
SUBTOTAL	295.13	2226.82	543.88	1158.92
TOTAL	18790.21	73276.93	61376.92	141349.24

TABLE 1. COST OF AIR AND WATER POLLUTION CONTROL (IN MILLIONS OF 1977 DOLLARS) Continued

			ANNUAL COSTS	
	1977	1970–77	1977–81	1977–86
COSTS TO GOVERNMENT	4588.00	12300.90	25130.00	71720.00
FUELS & ENERGY				
COAL MINING & COAL CLEANING	69.44	212.23	280.07	677.45
OIL & GAS EXTRACTION & PROCESSING	1453.15	3835.18	6289.13	15079.90
PETROLEUM REFINING	638.69	1643.40	3279.71	8268.68
ELECTRIC UTILITIES	4828.77	11372.57	31215.88	82319.19
COAL GASIFICATION	0.0	0.0	174.18	1919.48
SUBTOTAL	5945.70	13913.07	36783.56	97832.44
MOBILE SOURCES	5850.74	38203.01	33146.74	92068.00
FOOD PROCESSING				
FEEDLOTS & MEAT PROCESSING	39.08	98.90	293.18	947.35
OTHER FOOD PROCESSING	1453.15	3835.18	6289.13	15078.90
SUBTOTAL	1492.23	3934.08	6582.31	16027.25
CHEMICALS				
BASIC INORGANIC CHEMICALS	276.35	747.94	1469.03	3935.04
ORGANIC CHEMICALS	421.24	791.90	2589.27	7019.09
AGRICULTURAL CHEMICALS	117.50	223.86	601.37	1667.98
FORMULATED CHEMICALS	146.73	313.65	1070.45	3381.43
SUBTOTAL	961.82	2077.34	5730.12	16003.51
CONSTRUCTION MATERIALS	235.21	718.73	1094.42	2524.83
METALS				
ORE MINING & DRESSING	84.58	145.97	603.18	1340.06
IRON & STEEL	1075.86	3312.17	6595.23	18705.79
ALUMINUM	111.27	352.13	526.92	1236.31
COPPER	199.25	802.96	1011.18	2549.96
NONFERROUS METALS, FERROALLOYS, & FOUNDRIES	198.40	779.70	823.68	1820.02
SUBTOTAL	1669.37	5392.93	9569.18	25652.12
SOFTGOODS				
PULP & PAPER	659.01	1416.82	3014.37	8215.19
TEXTILES	27.42	64.01	1089.87	4499.59
LEATHER & RUBBER	47.68	95.93	254.54	707.69
SUBTOTAL	734.11	1576.76	4358.78	13422.47
MANUFACTURING				
ELECTROPLATING	141.74	316.31	751.27	1771.01
SURFACE COATINGS	0.0	0.0	374.38	1858.20
FURNITURE MANUFACTURING	0.0	0.0	1.37	12.59
SUBTOTAL	141.74	316.31	1127.02	3641.80
SERVICES				
DRYCLEANING	23.07	86.06	95.58	156.53
HOSPITALS	16.37	34.69	79.65	219.62
PHOTOGRAPHIC PROCESSING	4.46	8.45	21.99	59.67
SUBTOTAL	43.90	129.21	197.22	435.81
WASTE DISPOSAL				
OPEN DUMPS & OPEN BURNING	1112.22	4762.36	5419.23	15076.59
MUNICIPAL WASTE INCINERATION	6.05	24.19	30.57	75.14
SUBTOTAL	1118.27	4786.55	5449.80	15151.73
OTHER INDUSTRIAL COSTS				
INDUSTRIAL & COMMERCIAL HEATING BOILERS	349.02	1189.57	1547.50	3634.55
INDUSTRIAL, COMMERCIAL & BLDG. INCINERATORS	93.09	270.33	596.43	2013.17
SUBTOTAL	442.11	1459.90	2143.93	5647.71
TOTAL	23223.21	84808.80	131313.08	360127.75

TABLE 2. COST OF AIR POLLUTION CONTROL (IN MILLIONS OF 1977 DOLLARS)

			INVESTMENT	
	1977	1970–77	1977–81	1977–86
COSTS TO GOVERNMENT	0.0	0.0	0.0	0.0
FUELS & ENERGY				
COAL MINING & COAL CLEANING	12.88	75.24	0.0	0.0
OIL & GAS EXTRACTION & PROCESSING	9.35	19.92	45.75	127.65
PETROLEUM REFINING	167.23	745.85	393.72	537.17
ELECTRIC UTILITIES	2850.92	11489.03	10174.58	18276.43
COAL GASIFICATION	0.0	0.0	70.44	412.03
SUBTOTAL	3040.38	12330.04	10684.48	19353.28
MOBILE SOURCES	2912.00	12050.09	17234.55	49051.55
FOOD PROCESSING				
OTHER FOOD PROCESSING	442.04	3323.80	769.95	1781.34
CHEMICALS				
BASIC INORGANIC CHEMICALS	74.55	517.56	145.45	327.10
ORGANIC CHEMICALS	83.86	115.10	190.39	257.63
AGRICULTURAL CHEMICALS	4.97	41.85	5.23	9.59
FORMULATED CHEMICALS	4.85	34.33	8.59	13.14
SUBTOTAL	168.23	708.84	349.66	612.46
CONSTRUCTION MATERIALS	55.78	501.37	96.31	160.46
METALS				
IRON & STEEL	320.28	1258.04	1281.12	1921.68
ALUMINUM	51.84	359.91	117.86	363.17
COPPER	90.00	1094.00	171.70	986.00
NONFERROUS METALS, FERROALLOYS, & FOUNDRIES	64.44	659.70	58.00	139.67
SUBTOTAL	526.56	3371.65	1628.61	3410.52
SOFTGOODS				
PULP & PAPER	264.00	921.00	429.50	442.00
MANUFACTURING				
SURFACE COATINGS	0.0	0.0	658.82	1707.64
SERVICES				
DRYCLEANING	10.04	141.75	6.75	13.27
WASTE DISPOSAL				
OPEN DUMPS & OPEN BURNING	145.33	1744.12	718.62	2023.34
MUNICIPAL WASTE INCINERATION	4.29	27.11	11.31	24.72
SUBTOTAL	149.62	1771.23	729.93	2048.06
OTHER INDUSTRIAL COSTS				
INDUSTRIAL & COMMERCIAL HEATING BOILER	238.11	1970.21	268.26	465.11
INDUSTRIAL, COMMERCIAL & BLDG. INCINERATORS	57.02	256.61	275.62	693.80
SUBTOTAL	295.13	2226.82	543.88	1158.92
TOTAL	7863.78	37346.59	33132.45	79739.49

TABLE 2. COST OF AIR POLLUTION CONTROL (IN MILLIONS OF 1977 DOLLARS) Continued

			ANNUAL COSTS	
	1977	1970–77	1977–81	1977–86
COSTS TO GOVERNMENT	539.00	539.00	2787.00	5597.00
FUELS & ENERGY				
COAL MINING & COAL CLEANING	13.13	64.47	52.51	109.56
OIL & GAS EXTRACTION & PROCESSING	27.56	137.13	134.68	375.13
PETROLEUM REFINING	136.12	400.56	773.86	1981.58
ELECTRIC UTILITIES	4106.02	10076.90	28810.93	76395.50
COAL GASIFICATION	0.0	0.0	174.18	1919.48
SUBTOTAL	4282.83	10679.06	29946.16	80781.25
MOBILE SOURCES	5850.74	38203.01	33146.74	92068.00
FOOD PROCESSING				
OTHER FOOD PROCESSING	573.55	1903.77	2679.99	6769.09
CHEMICALS				
BASIC INORGANIC CHEMICALS	139.82	462.72	681.97	1657.49
ORGANIC CHEMICALS	56.64	124.71	438.78	1141.87
AGRICULTURAL CHEMICALS	14.55	50.07	63.72	137.39
FORMULATED CHEMICALS	11.11	36.55	52.33	117.96
SUBTOTAL	222.12	674.05	1236.80	3054.71
CONSTRUCTION MATERIALS	159.39	576.10	720.14	1562.65
METALS				
IRON & STEEL	519.20	1327.59	3473.60	9900.35
ALUMINUM	95.96	323.82	444.67	1007.86
COPPER	199.25	802.96	1011.18	2549.96
NONFERROUS METALS, FERROALLOYS, & FOUNDRIES	176.00	716.44	730.83	1571.24
SUBTOTAL	990.42	3170.78	5660.26	15029.38
SOFTGOODS				
PULP & PAPER	130.48	270.62	733.17	1736.53
MANUFACTURING				
SURFACE COATINGS	0.0	0.0	374.38	1858.20
SERVICES				
DRYCLEANING	23.07	86.06	95.58	156.53
WASTE DISPOSAL				
OPEN DUMPS & OPEN BURNING	1112.22	4762.36	5419.23	15076.59
MUNICIPAL WASTE INCINERATION	6.05	24.19	30.57	75.14
SUBTOTAL	1118.27	4786.55	5449.80	15151.73
OTHER INDUSTRIAL COSTS				
INDUSTRIAL & COMMERCIAL HEATING BOILER	349.02	1189.57	1547.50	3634.55
INDUSTRIAL, COMMERCIAL & BLDG. INCINERATORS	93.09	270.33	596.43	2013.17
SUBTOTAL	442.10	1459.90	2143.93	5647.71
TOTAL	14331.98	62348.90	84973.95	229412.79

TABLE 3. COST OF WATER POLLUTION CONTROL
(IN MILLIONS OF 1977 DOLLARS)

			INVESTMENT	
	1977	1972–77	1977–81	1977–86
COSTS TO GOVERNMENT	5065.00	21593.00	19677.00	45882.00
FUELS & ENERGY				
COAL MINING & COAL CLEANING	9.24	53.50	16.25	30.34
OIL & GAS EXTRACTION & PROCESSING	554.61	892.33	337.42	651.78
PETROLEUM REFINING	735.68	2575.30	668.80	789.59
ELECTRIC UTILITIES	1026.78	1638.67	877.15	2637.12
SUBTOTAL	2326.31	5159.80	1899.62	4108.83
FOOD PROCESSING				
FEEDLOTS & MEAT PROCESSING	36.52	122.74	159.82	241.12
OTHER FOOD PROCESSING	247.56	829.28	221.11	392.71
SUBTOTAL	284.08	952.02	380.93	576.01
CHEMICALS				
BASIC INORGANIC CHEMICALS	179.78	471.65	379.38	547.91
ORGANIC CHEMICALS	925.79	1945.80	1259.25	2689.54
AGRICULTURAL CHEMICALS	120.27	228.25	147.64	266.45
FORMULATED CHEMICALS	253.53	676.89	1348.55	2111.37
SUBTOTAL	1479.37	3322.58	3134.82	5615.27
CONSTRUCTION MATERIALS	45.92	176.52	102.15	151.79
METALS				
ORE MINING & DRESSING	152.50	389.59	251.00	251.00
IRON & STEEL	660.94	1410.22	1056.48	1692.30
ALUMINUM	19.51	40.45	29.21	46.95
NONFERROUS METALS, FERROALLOYS, & FOUNDRIES	4.98	72.18	5.05	11.24
SUBTOTAL	837.93	1912.44	1341.74	2001.49
SOFTGOODS				
PULP & PAPER	700.00	2178.75	441.25	1511.05
TEXTILES	24.21	87.84	1030.21	1410.16
LEATHER & RUBBER	82.93	198.40	121.20	181.72
SUBTOTAL	807.13	2464.99	1592.66	3102.92
MANUFACTURING				
ELECTROPLATING	49.79	264.74	81.55	81.55
FURNITURE MANUFACTURING	0.0	0.0	2.80	4.80
SUBTOTAL	49.79	264.74	84.35	86.35
SERVICES				
HOSPITALS	24.50	69.77	25.65	69.56
PHOTOGRAPHIC PROCESSING	6.21	14.47	5.59	15.69
SUBTOTAL	30.71	84.23	31.24	85.26
TOTAL	10926.43	35930.34	28244.47	61609.75

TABLE 3. COST OF WATER POLLUTION CONTROL (IN MILLIONS OF 1977 DOLLARS) Continued

			ANNUAL COSTS	
	1977	1972–77	1977–81	1977–86
COSTS TO GOVERNMENT	4049.00	11761.90	22343.00	66123.00
FUELS & ENERGY				
COAL MINING & COAL CLEANING	56.31	147.75	227.56	567.89
OIL & GAS EXTRACTION & PROCESSING	381.24	547.74	1699.04	4272.51
PETROLEUM REFINING	502.57	1242.84	2505.84	6287.09
ELECTRIC UTILITIES	722.76	1295.68	2404.96	5923.74
SUBTOTAL	1662.88	3234.01	6837.40	17051.23
FOOD PROCESSING				
FEEDLOTS & MEAT PROCESSING	39.08	98.90	293.18	947.35
OTHER FOOD PROCESSING	879.60	1931.41	3609.14	8310.81
SUBTOTAL	918.68	2030.31	3902.32	9258.16
CHEMICALS				
BASIC INORGANIC CHEMICALS	136.53	285.22	787.06	2277.54
ORGANIC CHEMICALS	364.60	667.19	2150.49	5877.23
AGRICULTURAL CHEMICALS	102.95	173.79	537.65	1530.59
FORMULATED CHEMICALS	135.62	277.10	1018.12	3263.47
SUBTOTAL	739.70	1403.30	4493.33	12948.81
CONSTRUCTION MATERIALS	75.82	142.64	374.28	962.17
METALS				
ORE MINING & DRESSING	84.58	145.97	603.18	1340.06
IRON & STEEL	556.66	1984.58	3121.63	8805.44
ALUMINUM	15.31	28.31	82.26	228.45
NONFERROUS METALS, FERROALLOYS, & FOUNDRIES	22.40	63.29	101.85	248.79
SUBTOTAL	678.95	2222.15	3908.92	10622.74
SOFTGOODS				
PULP & PAPER	528.53	1146.20	2281.20	6478.66
TEXTILES	27.42	64.01	1089.87	4499.59
LEATHER & RUBBER	47.68	95.93	254.54	707.69
SUBTOTAL	603.63	1306.14	3625.61	11685.94
MANUFACTURING				
ELECTROPLATING	141.74	316.31	751.27	1771.01
FURNITURE MANUFACTURING	0.0	0.0	1.37	12.59
SUBTOTAL	141.74	316.31	752.64	1783.60
SERVICES				
HOSPITALS	16.37	34.69	79.65	219.62
PHOTOGRAPHIC PROCESSING	4.46	8.45	21.99	59.67
SUBTOTAL	20.83	43.15	101.64	279.28
TOTAL	8891.23	22459.90	46339.13	130714.96

as mineral mining, production of cement, lime, asphalt concrete, glass, structural clay products, asbestos, paving and roofing materials, timber products processing, and glass and fiberglass insulation. The *Nonferrous Metals* group includes the production of primary lead, zinc, magnesium, and other metals, and secondary aluminum, copper, lead, and zinc, as well as the production of ferroalloys and operations of iron and steel foundries. Further details on any group may be found via the key to aggregation given at the end of this summary, or the individual chapters of the report.

COMPARISON OF COSTS

In terms of the combined costs given in Table 1, the highest levels of expenditures are associated with the Energy Industries (largely electric power plants and petroleum refining) and Mobile Sources. The balance of the industry groups fall into either an intermediate range of expenditures, e.g., Food Processing, Chemical Industries, Metals, Softgoods, Waste Disposal, and Industrial Heating, or into a lower range of expenditures, e.g., the Construction Materials, Manufacturing, and Service groups.

The estimates reported allow a broad comparison of past and future expenditures. One observation is that investment to meet air pollution control regulations over the entire 1970–1986 period will be about 20 percent greater than investment to meet water pollution control regulations. A further observation is that, although the investments for air pollution control over the entire period are higher, sunk investment costs (i.e., before 1977) are roughly equal for air and water pollution control. This overall observation is, of course, subject to qualification in instances of individual industries.

The 1977 annualized cost of pollution control due to Federal Regulations was estimated to be $23 billion, or about one percent of 1977 GNP. The cumulative cost from 1970 to 1977 was $84.8 billion, and the projected cost over the period 1977 to 1986 is estimated at $360 billion.

In Table 2, (Air Pollution Control Costs) the groups showing the largest portions of investment costs include the Energy Industries (specifically, power plants), and Mobile Sources. The Mobile Sources costs include costs for lead phase-down and lead-free gasoline production; these elements of cost may be associated with the Petroleum Refining Industry in other studies. The next largest range of expenditures are those shown for the Metals and Food Processing groups.

Some of the individual features which may be noted in Table 2 (Air Pollution Control Costs) include the singularly high levels of expenditures for the control of Mobile Sources; these costs reflect the projected automobile populations that contain pollution control, as well as increasing stringency of regulations. The costs reported for electric utilities do not include any control costs stemming from the 1977 Amendments. The cost estimate for the electric utilities industry reflects the application of a mix of control technologies and fuel switching to achieve compliance.

The estimated costs for the metals industry group show the costs for the three major metals: steel, aluminum, and copper, with future investment costs for both the steel and copper industry estimated as more than the investment made up to 1977.

In Table 3 (Water Pollution Control Costs), the highest level of expenditure is that for the energy industry (largely for Petroleum Refining and, again, electric power plants) with the next highest levels of expenditures shown for the Chemical Industries (principally the organic chemicals industry), and for the so called "Softgoods" group; almost all the latter costs are associated with the pulp and paper industry.

The water pollution control costs in Table 3 include Federal grants for construction of municipal treatment plants as an investment expenditure. The cost of water pollution control for the electric utilities given in the table has, as a major component, the cost to meet thermal limits on discharge water and replacement of capacity lost to the operation of the required cooling towers. The Organic Chemicals and Formulated Chemicals categories reflect areas of high anticipated future costs, with the Organic Chemicals industry an area of complex control requirements for all components of a variegated industry. The "Softgoods" group contains two noteworthy cost elements: the past and future cost for the pulp and paper industry and the estimated high future cost (related largely to compliance with the 1983-BAT regulations) for the textile industry

Table 3 does *not* include an estimate for the control of nonpoint sources. EPA has not yet issued regulations controlling nonpoint sources; and the control technology and degree of control is still uncertain. The Water Report contains a discussion of nonpoint sources (agriculture, silviculture, urban runoff and new construction runoff control) in Chapter 10.1. Preliminary estimates indicate that future investment needs will be about $58 billion in the next five years. No estimate is available on what portion of this investment need will actually be spent.

BENEFITS

Historically, the benefits research program at the EPA has given primary attention to developing the capabilities to compute national estimates of the total damage from pollution, i.e., estimating the potential benefits of eliminating pollution entirely. Basically, the program has categorized the various types of economic damages from pollution (medical bills, property damage, etc) by media and pollutant. Individual projects generally involved estimating the extent and value of the more important damages for which some data exist. At best, past studies have been used to defend overall EPA programs, though they may not have been all that useful for this purpose. There have been a few attempts to demonstrate the feasibility of evaluating the benefits of control of individual pollutants (e.g., EPA-sponsored analyses of nitrates, nonfluorinated halomethanes, chlorobenzilate, etc.) but these were not done in direct support of actual EPA regulatory decisions. The EPA has never applied comprehensive benefit estimation methodologies to a contemplated regulatory decision.

National Estimates

The national damage estimates have concentrated on air and water pollution control. Best EPA-generated estimates have been very crude, sometimes based on faulty or incomplete methodologies and always on inadequate data bases. The ranges defined by EPA and other estimates to date have been: air pollution damages from $2.0 billion to $35.4 billion and water pollution damages from $4.5 billion to $18.6 billion. These studies have been characterized as only providing crude, order-of-magnitude estimates of the damages.

The "Wyoming" Study

A recently completed EPA study done by a consortium of professors (primarily at the University of Wyoming) may provide significantly more reliable estimates of national morbidity and mortality damages from air pollution than the EPA has had before. The study also assesses potential benefits from air clean-up in the Los Angeles area. The results are:

- National mortality effects of $5 to $16 billion per year
- National morbidity effects of $36 billion per year
- Potential benefits of $0.65 to 0.95 billion per year from a 30 percent air clean up of the South Coast Basin of Southern California.

New Perspective on Damages

Besides suggesting that previous studies may have substantially underestimated both the health and other economic damages from air pollution, and thus the benefits of control, the new study and other recent work by many of the same environmental economists suggest a new perspective on air pollution damages and their measurement.

The new work indicates that the major air pollution damages are from increased chronic illness and from aesthetic effects like reduced visibility. This contrasts with earlier views that increased deaths were the major source of damage.

The economic damages attributable to increased air pollution-related deaths are roughly comparable to earlier studies, but this is largely accidental: although the new estimates of mortality effects are lower than earlier studies have indicated, these lower estimates are offset by higher estimates of the value society places on increased risk of death.

The study also concludes that many benefits, such as aesthetic ones, which are "traditionally viewed as intangible and thereby nonmeasurable can, in fact be measured" and can be made comparable to economic values expressed in the marketplace.

Derivation of New Health Estimates

The researchers derived their estimates of damage to health through two independent approaches. One approach examined data from the University of Michigan Survey Research Center on illnesses among a random selection of the U.S. population. This information was compared statistically with indicators of biological and social situation, life styles, income levels, physical environment, and air pollution levels in the county of residence. The analyses suggest the extent to which each indicator is associated with time lost from work because of illness.

The studies found statistically significant associations between lost work time because of chronic illness and ambient levels of both nitrogen dioxide and total suspended particulates. The researchers arrived at the $36 billion estimate for 60 percent control by projecting the relationship between lost time and particulate levels in their sample to the national urban population using the wage rates of the sample population to put a monetary value on the time lost from work. The authors emphasized, however, that their conclusions should be regarded as preliminary because of the short time they have worked with the data and the many combinations of explanatory hypotheses they will need to test.

In the second approach, the researchers concentrated on the death rates in 60 cities across the country, comparing them to air pollution levels and other factors that might influence those rates such as smoking, doctors per capita, and diet. The researchers found statistically significant associations between death from pneumonia and influenza and the level of sulfur dioxide. The study valued the benefits that would result from reduced mortality if there were a 60 percent improvement in air quality at $5 to $16 billion annually.

Los Angeles Benefits Also Large

In addition to studying health damages from air pollution, the same study also attempts to quantify air pollution damages in one air quality region—the Los Angeles Basin. It found that a 30 percent improvement in air quality would provide benefits of $650 to $950 million per year (or $350 to $500 per household) for this city alone.

This part of the study used interview surveys and analyses of property values to support its conclusions. In the interview survey people were first given a subjective understanding of the health effects and location of Los Angeles smog using maps of pollution levels (which varied from poor to quite good) throughout the Basin and later shown photographs of a view obscured by different levels of pollution. They were then asked how much they would be willing to pay for improved air quality. In the property value analyses, the researchers compared the selling prices of houses which were similar but which were located in areas experiencing different levels of pollution. The houses in the clean air areas had a substantially higher value than those in more polluted areas. The fact that the benefit estimates derived from the two approaches are similar lends credence to both.

In their interview survey, the researchers found that people living in the Los Angeles Basin believe aesthetic effects such as impairment of visibility account for 22 percent to 55 percent of the damages associated with air pollution. These findings are consistent with an earlier survey many of the same researchers undertook for the Electric Power Research Institute, which found that people living in the Four Corners area of the Southwest would pay an average of $90 a year to avoid having visibility reduced by 50 miles, i.e., from 75 to 25 miles.

Ongoing Pollutant-Specific Benefits Study

Since FY75, the EPA has contracted for 12 pollutant assessments from the National Academy of Science which were to include economic, and where possible, benefit-cost analyses. Of these assessments, two (halomethanes and nitrates) have been delivered, and three (chlorobenzilate, odors, and PCB's in the environment) are nearing completion and should be delivered in 1979. It appears that where adequate physical science data exist, benefit-cost analysis can contribute to Agency decision making (as applied to specific regulations proposed by the Agency).

Plans for a Benefits Study Program

To get reliable estimates, in the near future, of national or regional benefits, the EPA must push the state-of-the-art further and faster than has been done so far. It will be necessary to devote significant resources to improving existing data bases.

Unfortunately, breakthroughs in benefits estimates are like those in other scientific fields, uncertain and expensive. In addition to continued "basic" research, there is a need to test the usefulness of a benefit-cost approach in analysing specific proposed EPA regulations on a prototype basis. The prototype basis, rather than the immediate application of benefit-cost analysis to all or most EPA regulations, is likely to be taken so that the Agency can first gain experience and find out if some of the carcinogen-related problems can be resolved. Whether additional research will be needed to assist the EPA in applying benefit-cost analysis to individual decisions is not yet clear, but may become more so as the proposed prototype effort is implemented in the next year.

THE ECONOMIC IMPACT OF EPA'S PROGRAM

This section is included to provide some perspective as to the economic effects of EPA programs. Widely disparate views on the economic impact of EPA's program have been expressed by some environmentalists — who say the program stimulates the economy and creates jobs — and by some businessmen — who say the program causes capital shortages and inflation in boom times and causes unemployment and stifles profitability in recessionary times.

The truth probably lies somewhere in between. While costs of pollution programs are high in absolute terms, the overall effects on prices, GNP, and employment are projected to be small and neither strongly positive nor negative in the long run.

Most concern about economic effects should be focused on a few heavily polluting industries which either are very capital-intensive materials producing industries or are characterized by many economically marginal operations. Of key importance for these industries are (a) concerns about limits on expansion due to capital shortfalls or siting constraints posed by environmental regulations and (2) the effects of these limits on growth in these and related industries.

This section does not discuss whether environmental programs (or various elements of them) have favorable benefit/cost ratios, since few credible benefits data have been generated which would allow such analysis. This section does briefly detail what is and is not known about the costs, macroeconomic and microeconomic impacts, energy impacts, and key economic impact issues associated with the environmental program.

Costs

The Federal pollution control program is projected to cost about*$360 billion in the period 1977-86* above expenditure levels which would have resulted without new Federal requirements since 1970. About $229 billion, or about 2/3 of these expenditures are the result of the Clean Air Act. Capital investment for Federally-required controls will be about $142 billion over the same period. About $81 billion of this total (57%) is as a result of the Clean Air Act.

The 1977 annualized cost of pollution control due to Federal Regulations was estimated to be $23.2 billion, or about one percent of 1977 GNP. Air pollution control costs were $14.3 billion in 1977, or about 62% of the combined air and water costs.

Total (air and water) pollution abatement investment by industry (excluding Mobile Sources and Cost to Governments) was $10.8 billion in 1977. This represents about 5.8% of 1977 fixed nonresidential private investment. Consumer investment for Mobile Source pollution control was slightly under $3 billion in 1977. This represents about 3.6% of 1977 consumer expenditures for motor vehicles and parts.

Macroeconomic Impacts

These costs can be put in perspective by looking at their macroeconomic effect on the economy. The magnitudes of these effects depend upon the general state of the economy. In a slack economy pollution control investment can stimulate growth and employment with little real effect on prices, while in a tight economy such investment can increase prices and tend to replace other capital spending plans with a relatively small effect on employment. Macroeconomic forecasts can project these effects, but only with a wide band of uncertainty.

Price and Growth Effects — A Data Resources, Inc. (DRI) forecast prepared for EPA and CEQ in January 1979 shows that *the Consumer Price Index is currently about 2.7% higher* than it would have been without Federal pollution requirements and that by 1986 this difference will be about 3.6%, meaning that *consumer prices will increase between 0.2% and 0.3% per year more* than they would without these requirements over the period 1970–1986.

DRI estimates that GNP is currently very marginally higher than it would have been because Federal pollution requirements have caused use of capital and other resources that would not otherwise have been used. As the economy improves, environmental investment will increasingly be made instead of, rather than in addition to, other expenditures. DRI estimates that by 1986 *GNP will be almost 1.0% lower* than it would have been without Federal pollution requirements.

These estimated effects on prices and GNP use conventional measures for these variables. Since these measures do not take into account the benefits of *the environmental programs in terms of improved public health and welfare, these forecasts exaggerate the negative impacts on inflation and economic growth.*

Employment Effects — Employment is affected in a number of ways by environmental requirements. The program directly creates jobs in the construction (46,000 on-site jobs on EPA-funded sewage treatment projects in July 1976, with an equivalent number of off-site jobs) and the pollution control manufacturing industry (Arthur D. Little, Inc., estimates current employment to be nearly 36,000 and projects employment to grow to nearly 44,000 in this industry by 1983 as a result of the 1970 and 1972 air and water legislation), with many more indirect jobs stimulated by these expenditures.

On the other hand, when pollution control costs result in higher prices, lower demand and hence lower production and lower employment result. Furthermore, some transitional unemployment results from closing of marginal plants which cannot afford to comply with environmental requirements. Since January 1971, 132 closures involving nearly 24,500 jobs have occurred for which the firm has said that pollution requirements were a significant factor; 40 closures involved Federal action.

The combination of these factors according to the DRI macroeconomic projection will result in *increased employment through 1986 due to the stimulative effect of pollution control investment.* The jobs created in manufacturing, installing, and operating/maintaining pollution control equipment outweigh the dampening effect of higher prices on economic growth. DRI estimates the unemployment rate to be about 0.2% lower in 1979, 0.4% lower in both 1980 and 1981, and 0.2% lower in 1986 due to Federal pollution requirements.

OTHER METHODOLOGIES

This report is based primarily on a model plant analysis. A detailed description of the methodology used to generate these estimates can be found in the Introduction to the Air Report. Various other sources have estimated the cost of pollution control using other techniques. This section discusses some of these other sources and how they differ from this report.

Bureau of Economic Analysis

The Bureau of Economic Analysis (BEA), U.S. Department of Commerce, publishes the results of an annual survey of industries detailing capital expenditures for air, water and solid waste pollution abatement. The survey requests information on total plant and equipment expenditures for pollution abatement, not just that attributable to Federal legislation.

One of the major problems with the BEA survey, is that it samples company enterprises, not actual plants. A company is categorized by its major product. For example, if a large petroleum company owns a textile mill, any pollution control investment at the textile mill would be classified under petroleum refining. Thus, while the aggregate BEA estimates are quite useful, the individual industry-specific estimates reveal little about the cost to a specific industrial process.

Bureau of the Census

The Bureau of the Census, U.S. Department of Commerce, publishes the results of an annual survey of manufacturing establishments detailing both capital investment and operating costs for pollution abatement. The survey asks for total expenditures, not just that due to Federal legislation. Unlike BEA, the Census survey is based on a plant or establishment classification. However, it only includes manufacturing industries.

One of the main problems with the Census survey is that depreciation is included as a part of operating costs. Only total operating costs are reported by air, water or solid waste. The specific line items of operating costs (i.e., labor, materials and depreciation) are not broken out by media. Since the depreciable life of air and water pollution abatement equipment vary considerably, it is impossible to accurately subtract out depreciation. Furthermore, the depreciation expenses are likely to reflect changes in tax provisions that affect depreciation expenses for tax purposes. Thus, the inclusion of depreciation limits the reliability of this survey in estimating operating and maintenance costs.

McGraw-Hill Survey

The Economics Department of McGraw-Hill Publications Company issues the results of an annual survey of pollution control expenditures. The methodology used for this survey has never been revealed by the Company, and thus, it is difficult to compare with other estimates.

Business Roundtable

The Business Roundtable, a group representing large corporations, recently released a study of the cost of Federal regulation. The study covered 48 companies, mostly among the nation's largest. EPA regulations were one segment of the study, which is the first survey to request *incremental* expenditures, i.e. only those expenditures made as a result of Federal legislation. Since the survey was lengthy and detailed, such expenses as paperwork, meetings with government officials and other administrative expenses were included in the cost estimates. However, these costs were reported combined with operating costs. Thus, the usefulness of this information is somewhat limited.

Since the sample size was so small, not random, and did not reflect a cross-section of American business, no extrapolation of this survey's results can be made. It would be unrealistic to make any generalizations about the National costs of pollution abatement based on this study. Nevertheless, The Business Roundtable Study contains much useful information, especially in terms of cost accounting methodology.

KEY TO AGGREGATED COST TABLES IN EXECUTIVE SUMMARY

Table Entries	"Air" Report Chapter Numbers	"Water" Report Chapter Numbers
Cost to Government	2	2
Fuels & Energy		
Coal Mining & Coal Cleaning	3.5	3.1
Oil & Gas Extraction & Processing	3.3	3.2
Petroleum Refining	3.4	3.3
Electric Utilities	3.1	3.4
Coal Gasification	3.6	—
Mobile Sources		
Food Processing		
Feedlots & Meat Processing	—	8.6, 8.7
Other Food Processing	9.3, 9.4	8.1, 8.2, 8.3 8.4,8.5
Chemicals		
Basic Inorganic Chemicals	5.4, 5.7	4.2.1, 4.2.2
Agricultural Chemicals	5.3, 5.5, 5.6	4.8, 4.9, 4.10, 10.2
Formulated Chemicals	8.1	4.5, 4.6, 4.7, 4.11 4.12, 7.3, 9.1
Construction Materials	7.1, 7.2, 7.3, 7.4	6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 7.1
Metals		
Ore Mining & Dressing	—	5.1
Iron & Steel	6.1	5.2
Aluminum	6.5	5.5
Copper	6.6	—
Nonferrous Metals, Ferroalloys, & Foundries	6.2, 6.3, 6.4, 6.7 6.8, 6.9, 6.10, 6.11, 6.12	5.3, 5.4, 5.6, 5.7
Softgoods		
Pulp & Paper	9.1, 9.2	7.4
Textiles	—	4.14
Leather & Rubber	—	4.4, 8.8
Manufacturing		
Electroplating	—	5.8
Surface Coatings	8.2	—
Furniture Manufacture	—	7.2
Services		
Drycleaning	8.3	—
Hospitals	—	9.2
Photographic Processing	—	4.13
Waste Disposal		
Open Burning & Open Dumps	10.1	—
Municipal Incineration	10.2, 10.3	—
Other Industrial Costs		
Industrial & Commercial Heating Boilers	3.2	—
Industrial, Commercial, & Building Incinerators	10.5	—

THE COST OF CLEAN AIR

1. INTRODUCTION AND SUMMARY

PURPOSE AND SCOPE

Section 312(a) of the Clean Air Act Amendments of 1970 (referred to as "Act" and "CAA") requires an annual report on the prospective costs and impacts of governmental and private efforts to carry out the provisions of the Act. This report is submitted in response to the Act.

National Cost estimates are presented for governmental programs as well as those for the control of the major sources of air pollution. For this purpose the sources of air pollution are broadly divided into several categories: energy industries, transportation sources, and other industrial sources. Coverage includes not only those criteria pollutants for which national ambient air quality standards have been promulgated, but also pollutants covered by accepted and proposed hazardous air-pollutant-emission standards and by new source performance standards.

Estimates of costs, benefits, and impacts reported herein are based, wherever possible, upon Federal regulations or those specified by the states in implementation plans submitted to EPA. All air-pollution control costs in this report are in July 1, 1977 dollars. Where costs were developed for earlier years, these were updated to 1977 dollars using the implicit price deflater of the gross national product (fixed non-residential investment part).

This report does not presume to include all costs of abating air pollution. Even before the Clean Air Act of 1970, costs were incurred in response to obvious pollution problems and to local legislation. Therefore, the costs herein are estimated incremental costs, over and above any cost of control incurred or the level of control practiced prior to the Act of 1970.

Fiscal year 1971 was judged as the appropriate baseline from which incremental costs are to be assessed. This is in keeping with the passage of the clearer and more specific Clean Air Amendments of 1970, and with the wording of Section 312(a) of that legislation.

Within this framework, the estimated direct costs of air-pollution control for industrial and other sources are detailed. Investments are projected through 1986. A large number of simplifying assumptions were necessary. Industry and motor-vehicle growth and technology trends were forecast and are described in their appropriate places in the text. Regulations which are pending under the Clean Air Act and which reasonably can be expected to become law were included in the calculations. The best available information on control technologies, associated control costs, and related information was employed. This information is being modified and updated continuously by the growing experience with applied emissions-control systems. The situation has been complicated further by recent uncertainty in the overall fuels/energy situation.

It should be noted that this document specifically does not dictate EPA policy with regard to the application of presently available or projected emissions-control technology to any industry or activity. Simplifying assumptions were required in order to estimate the effect of EPA regulations on the source industries included herein. The control technologies assumed in providing these estimates are neither specifically required by law nor by EPA; no interpretation of the contents of this document to the contrary should be made.

COSTS OF IMPLEMENTING THE ACT

The 1977 Amendments to the Clean Air Act were enacted by the Congress during the period in which these estimated costs were being generated. Further, there is a period of time between the issuance of direction by the Congress and the completion of specific actions by EPA which can be analyzed in terms of costs. Thus, any costs to industry involved in complying with the directions in the 1977 amendments cannot yet be expressed in the costs reported here. The Federal expenditures detailed in the amendments are reported here under Costs to Government.

A uniform costing methodology has been applied to the industrial sectors incurring air pollution abatement costs. Being free of the requirements of macroscopic input-output economic models, this methodology permits an examination of each industrial sector at the most desirable level of disaggregation.

Estimates of the capital investments and annualized costs required for implementing the Act in 1977 and over the periods 1970–77, 1977–81 and 1977–1986, are summarized in Table 1–1. Each number in Table 1–1 is repeated in the appropriate chapter of this report, where the assumptions and background data are presented and discussed.

TABLE 1.-1. AIR POLLUTION ABATEMENT COSTS (IN MILLIONS OF 1977 DOLLARS)

	1977	1970–77	1977–81	1977–86
TOTAL INVESTMENT	7863.78	37346.59	33132.45	79739.49
TOTAL ANNUAL COSTS	14331.98	62348.90	84973.95	229412.79

INVESTMENT

	1977	1970–77	1977–81	1977–86
COSTS TO GOVERNMENT	0.0	0.0	0.0	0.0

ANNUAL COSTS

	1977	1970–77	1977–81	1977–86
COSTS TO GOVERNMENT	539.00	539.00	2787.00	5597.00

	1970	1970–77	1977–81	1977–86
MOBILE SOURCES				
INVESTMENT	2912.00	12050.09	17234.55	49051.55
ANNUAL COSTS	5850.74	38203.01	33146.74	92068.00
ENERGY INDUSTRIES				
FOSSIL FUEL POWER PLANTS	2850.92	11489.03	10174.58	18276.43
COMMERCIAL & INDUSTRIAL HEATING BOILERS	238.11	1970.21	268.26	465.11
FUELS INDUSTRIES				
NATURAL GAS PROCESSING	9.35	19.92	45.75	127.65
PETROLEUM REFINING	167.23	745.85	393.72	537.17
COAL CLEANING	12.88	75.24	0.0	0.0
COAL GASIFICATION	0.0	0.0	70.44	412.03
TOTAL INVESTMENT	3278.49	14300.23	10952.74	19818.39

ANNUAL COSTS

	1977	1970–77	1977–81	1977–86
FOSSIL FUEL POWER PLANTS	4106.02	10076.90	28810.93	76395.50
COMMERCIAL & INDUSTRIAL HEATING BOILERS	349.02	1189.57	1547.50	3634.55
FUELS INDUSTRIES				
NATURAL GAS PROCESSING	27.56	137.13	134.67	375.13
PETROLEUM REFINING	136.12	400.56	773.86	1981.58
COAL CLEANING	13.13	64.47	52.51	109.56
COAL GASIFICATION	0.0	0.0	174.18	1919.48
TOTAL ANNUAL COSTS	4631.83	11868.63	31493.64	84415.62

INVESTMENT

	1977	1970–77	1977–81	1977–86
CHEMICAL INDUSTRIES				
PETROCHEMICALS	4.47	27.63	9.37	22.06
VINYL CHLORIDE	79.39	87.47	181.02	235.57
NITRIC ACID	3.98	34.34	3.26	4.80
SULFURIC ACID	72.58	499.05	144.27	325.92
PHOSPHATE FERTILIZER	0.0	0.0	0.0	0.0
NON-FERTILIZER PHOSPHATES	1.00	7.51	1.97	4.79
MERCURY-CELL CHLOR-ALKALI	1.97	18.52	1.18	1.18
TOTAL INVESTMENT	163.38	674.51	341.08	594.32

ANNUAL COSTS

	1977	1970–77	1977–81	1977–86
PETROCHEMICALS	29.21	94.74	142.72	376.15
VINYL CHLORIDE	27.44	29.97	296.05	765.72
NITRIC ACID	12.99	44.91	56.35	121.26
SULFURIC ACID	131.59	433.89	646.93	1586.17
PHOSPHATE FERTILIZER	0.0	0.0	0.0	0.0
NON-FERTILIZER PHOSPHATES	1.56	5.17	7.37	16.12
MERCURY-CELL CHLOR-ALKALI	8.24	28.83	35.05	71.32
TOTAL ANNUAL COSTS	211.01	637.50	1184.47	2936.75

TABLE 1.-1. AIR POLLUTION ABATEMENT COSTS (IN MILLIONS OF 1977 DOLLARS)

			INVESTMENT	
INDUSTRY	1977	1970–77	1977–81	1977–86
METALS INDUSTRIES				
IRON & STEEL	320.28	1258.04	1281.12	1921.68
IRON FOUNDRIES	6.03	46.67	8.04	28.02
STEEL FOUNDRIES	18.97	177.49	25.19	53.82
FERROALLOYS	24.63	328.79	0.0	0.0
PRIMARY ALUMINUM	51.84	359.91	117.86	363.17
PRIMARY COPPER	90.00	1094.00	171.70	986.00
PRIMARY LEAD	2.16	20.28	1.29	1.29
PRIMARY ZINC	6.56	42.13	13.21	30.20
SECONDARY ALUMINUM	2.44	15.64	5.28	12.41
SECONDARY BRASS	1.59	13.32	1.92	3.62
SECONDARY LEAD	1.75	12.42	2.88	6.02
SECONDARY ZINC	0.32	2.97	0.19	4.28
TOTAL INVESTMENT	526.56	3371.65	1628.67	3410.52

			ANNUAL COSTS	
	1977	1970–77	1977–81	1977–86
IRON & STEEL	519.20	1320.59	3473.60	9900.35
IRON FOUNDRIES	7.08	24.10	32.03	81.48
STEEL FOUNDRIES	47.78	170.26	208.19	494.37
FERROALLOYS	70.16	346.91	250.71	399.86
PRIMARY ALUMINUM	95.96	323.82	444.67	1007.86
PRIMARY COPPER	199.25	802.96	1011.18	2549.96
PRIMARY LEAD	4.02	14.14	17.11	30.24
PRIMARY ZINC	36.46	126.13	172.49	434.72
SECONDARY ALUMINUM	4.35	14.35	21.33	56.09
SECONDARY BRASS	2.77	9.31	12.66	30.56
SECONDARY LEAD	2.53	8.56	11.80	29.27
SECONDARY ZINC	0.86	2.65	4.51	14.66
TOTAL ANNUAL COSTS	990.42	3170.78	5660.26	15029.38

			INVESTMENT	
	1977	1970–77	1977–81	1977–86
QUARRYING & CONSTRUCTION INDUSTRIES				
CEMENT	4.44	14.58	18.04	41.24
CLAY CONSTRUCTION	11.04	96.06	10.24	15.66
LIME	14.67	137.94	8.80	8.80
ASPHALT	25.63	252.80	59.23	94.76
TOTAL INVESTMENT	55.78	501.37	96.31	160.46

			ANNUAL COSTS	
	1977	1970–77	1977–81	1977–86
CEMENT	3.29	7.48	24.22	79.18
CLAY CONSTRUCTION	37.32	128.59	162.81	337.42
LIME	25.05	87.68	106.61	230.90
ASPHALT	93.72	352.33	426.51	915.16
TOTAL ANNUAL COSTS	159.39	576.10	720.14	1562.65

TABLE 1.-1. AIR POLLUTION ABATEMENT COSTS (IN MILLIONS OF 1977 DOLLARS)

			INVESTMENT	
INDUSTRY	1977	1970–77	1977–81	1977–86
OTHER MANUFACTURING SERVICES				
PAINT MANUFACTURING	4.85	34.33	8.59	18.14
SURFACE COATING	0.0	0.0	658.82	1707.64
DRY CLEANING	10.04	141.75	6.75	13.27
TOTAL INVESTMENT	14.89	176.08	674.16	1739.06
			ANNUAL COSTS	
	1977	1970–77	1977–81	1977–86
PAINT MANUFACTURING	11.11	36.55	52.33	117.96
SURFACE COATING	0.0	0.0	374.38	1858.20
DRY CLEANING	23.07	86.06	95.58	156.53
TOTAL ANNUAL COSTS	34.18	122.61	522.30	2132.70
			INVESTMENT	
	1977	1970–77	1977–81	1977–86
FOREST PRODUCTS & AGRICULTURE				
KRAFT PAPER	250.00	862.50	412.50	425.00
NSSC PAPER	14.00	58.50	17.00	17.00
FEED MILLS	212.66	1700.61	323.81	812.97
GRAIN HANDLING	229.38	1623.20	446.14	968.38
TOTAL INVESTMENT	706.04	4244.80	1199.45	2223.34
			ANNUAL COSTS	
	1977	1970–77	1977–81	1977–86
KRAFT PAPER	120.80	247.75	678.20	1606.81
NSSC PAPER	9.68	22.87	54.97	129.72
FEED MILLS	301.52	1023.07	1370.31	3409.44
GRAIN HANDLING	272.03	880.71	1309.69	3359.65
TOTAL ANNUAL COSTS	704.03	2174.40	3413.17	8505.62

1.1 BASIS FOR COSTS

The costs reported here are developed and aggregated according to a self-consistent method. The comparison of these costs with costs for pollution control developed by other sources should be done with allowance for the constraints and conditions discussed below.

This report presents the costs of controlling air pollution as associated with the actions of the United States Environmental Protection Agency under the directions of Congress as given in the Clean Air Act and subsequent amendments. The specific regulations issued by the U.S. EPA may be identified in terms of the following classes of emissions or limitations.

- New Source Performance Standards
- Criteria Pollutant Limitations
- Hazardous Pollutant Standards
- National Ambient Air Quality Standards
- State Implementation Plans.

The Environmental Protection Agency has promulgated and is scheduled to continue promulgating specific regulations limiting the emissions of selected pollutants from various types of industrial plants to be built in the future; the development of these New Source Performance Standards (NSPS) thrusts upon the Agency the responsibility for the strategic selection of categories of industries and pollutants to be controlled under these regulations.

This report makes no attempt to analyze several new concepts to air pollution regulation, as follows:

- Reasonably Available Control Technology (RACT)
- Best Available Control Technology (BACT)
- Lowest Available Emission Rates (LAER).

These topics will be addressed in the future Cost of Clean Air reports.

Many of the pollutants controlled under the provisions of NSPS's correspond to the "criteria" pollutants that the Agency is called upon to control, namely

Sulfur Oxides (SO_x)
Nitrogen Oxides (NO_x)
Hydrocarbons (HC)
Particulates
Carbon Monoxide (CO).

Because the Agency has just recently added lead (Pb) to this listing, there has not been enough time to integrate the costs associated with proper control of lead.

The Agency is given a third approach to controlling specific air pollutants by classing them as "hazardous" pollutants; so far, pollutants regulated under this strategy include:

- asbestos
- beryllium
- mercury
- vinyl chloride.

However the Agency has also been called upon to issue National Ambient Air Quality Standards (NAAQS) specifying levels of "criteria pollutants" in ambient air which will protect human health (primary air quality standard), or, as a further development, the total environment (secondary air quality standard). These basic tasks of the Environmental Protection Agency have been expanded in manifold ways through both amendments to the law and interpretive rulings. The ramifications are discussed in part later in this Introduction and in part in Chapter 2. In connection with National Ambient Air Quality Standards, the EPA is further required to approve (or disapprove) the methods by which states propose to achieve the NAAQS's, those methods being formalized as State Implementation Plans (SIP's). Thus, costs imposed upon industry in the course of compliance with SIP's are reported here as resulting from an extension of Federal authority. This report, written in 1977 and 1978, does not include cost effects of the new SIPs to be submitted to EPA in 1979.

The costs reported here are those associated with compliance with the above array of regulations, and thus exclude money spent on air pollution control under various other motivations, such as:

- money spent prior to 1970, the date of the Clean Air Act
- money spent in voluntary clean-up
- money spent to comply with local or state regulations that are not motivated by the Clean Air Act (e.g. nuisance laws to control odors)
- money spent for air-pollution control devices which are installed for reasons of business economics (e.g. materials recovery).

The industries covered in this report are those identified as contributing significant amounts of pollutants to the air and therefore being the subjects of specific regulations. Such coverage of industry categories is the best possible depending on the available information. With the available resources, industry categories are added, updated, or treated in expanded detail according to the best judgement of those responsible for the conduct of the program, and with due regard for other cognizant and interested parties.

Definitions and Procedures

All costs are expressed in constant dollar values, specifically in "July 1, 1977 dollars." No inflation factor is included in the projection of costs into the future.

Unless otherwise specifically noted, all tabulations are in millions of 1977 dollars.

All physical quantities have been stated in metric tons or other metric units, usually with common "engineering usage" units stated in parentheses. It is recognized that "metric tons" is not a unit in the System Internationale and should most strictly be expressed as a "megagram." However, in recognition of the current stages of transition toward "metrification", and in the anticipation of a readership not totally technical, the "common" metric units have been used.

The time periods used for the aggregation of costs are based upon certain milestones:

1970—passage of the Clean Air Act
1977—base year of this report
1986—selected year for projection of costs.

The "cost year" used in this report is taken from July 1 to June 30. This type of year was chosen on the basis that many regulations require compliance by July 1 of a given year. (This is especially true in the companion effort on the cost of water pollution control.) Further, during the period of preparation of this report, the fiscal year was in a state of transition, being a period of more than twelve months. Government expenditures are reported in terms of fiscal years.

1.2 METHODOLOGY

The approach used to develop the costs reported here consists (in most cases) of a sequence which starts with a detailed description of an industry segment and progresses to an aggregated cost reported for an overall industry. This methodology involves the work of a specialist who is familiar with many of the technical and economic aspects of a specific industrial activity.

A typical pattern of cost development by a specialist/chapter-author involves the detailed identification of processes, emissions, regulations, control technology, and control costs specific to an identifiable group of industrial activities or plants. This group of plants is then, on the judgement of the specialist, expressed in terms of a number of model plants of various sizes which represent a close approach to the actual numbers and sizes of plants and the total capacity of that group of plants. A hypothetical example of such a listing might appear as:

Number of Plants	Average Capacity tons/day
80	4.0
40	15.5
12	27.0

An expression of cost is then developed for a given control technology which takes the form:

$$\text{Cost} = A(\text{Capacity})^B$$

where A is a coefficient
and B is an exponent.

This expression relates the cost of control to the size of the plant (larger plants usually benefit from economies of scale). The cost equation is developed from existing cost data in that industry group. The cost of control can be calculated for the above example list of plants by calculating the cost for each size and multiplying by the number of plants of that size and adding the three size categories together.

This approach may be broken down into groups of plants determined by all combinations of:

- regulations (e.g., SIP's and NSPS's)
- control technologies (e.g., scrubbers and baghouses)
- new and existing plants
- other specific conditions.

Each set of special conditions may be costed separately and summed into the aggregate industry cost. Also, the growth rate of the industry is expressed in terms of the model plants. For example, a common trend is for smaller plants to close and be replaced by larger plants. This is significant in pollution control costs in that the control costs would, in this example, benefit from the economies of larger-scale operations. The use of projected growth rates in production output expressed as percentage increases (compared to specific predictions of plant construction) was selected for this methodology because of the requirement for projections, which are beyond the plant construction plans of industry.

A special case of this methodology is occasionally encountered in industries with very few plants. In these cases, the "model" plants are actually the real plants and control costs are based on estimates for each individual plant.

In some cases, cost data are obtained from special economic studies of the impact of the cost of pollution control on a specific industry. These economic impact studies, usually commissioned by the Environmental Protection Agency, are used as the basis for costs in this report when appropriate. The use of these documents improves the consistency and coherency of this report with other EPA publications. In some of these economic reports, the plant sizes, specific costs, etc., are not presented in detail corresponding to the above procedure. In these cases, cost data from the economic study are transferred empirically (i.e., exogenously) to the computer and reported in a form consistent with the findings of the base document. In these cases, the reported costs do not necessarily conform to the standard format, e.g., new plant costs may not be identifiable as such (relative to costs for existing plants), although costs projected into the future include costs to both types of plants. Similarly the base document may not use the same breakdown of annual costs or the same interest rate as is normally used in the existing computer program. Nevertheless, the overall costs and timing of the costs are reported as developed in the designated source document.

In this connection, the timing of capital investment and the associated rate of accrual of the annual costs reflect both historical data (i.e., from 1970 to the most recent available data) as well as projected rates of investment by the particular industry segment. Projected rates of spending are largely based on the compliance date specified in the pertinent regulation with allowance for lead time required for fabrication, construction, and installation of the control technology involved. Also applied are investment schedules developed by other programs of the Environmental Protection Agency.

Thus, the information utilized in developing the costs reported here includes:

- a "model plant" description of the industry which includes a statement of industry capacity
- a statement of industry growth rate related to the model plant structure
- the identification of standards and dates of compliance
- the identification of costs of control for various plant sizes and regulations
- where appropriate the identification of money spent before the date of the Clean Air Act (1970) and in some cases, the timing of capital investment over the time period of interest
- the estimated life of the control equipment.

With these types of input, the computer program performs calculations, for each year in the period 1970 through 1986, of capacity based on each size class of model plant, and the cost of control for that class under the regulations pertinent for that year. At the year of compliance for New Source Performance Standards, all new expansion of capacity is costed according to the cost equation for new plants (usually different than for existing plants complying with the requirements of State Implementation Plans). The program thus generates a statement of capital investment, operating and maintenance costs, and annual costs for capital investment for each class of plants. These costs may be aggregated by industry segment, industry, or groups of industries for any year or span of years depending on the report desired.

For the calculation of the annual cost of capital, the computer program uses straight-line depreciation over the stated life of the control equipment and an interest rate of ten percent. It is understood that other systems of depreciation are used, that other interest rates are sometimes applicable, that "opportunity costs" for other uses of capital are not taken into account, and that tax write-offs are commonly applied to control equipment. The ten percent interest rate is used to signify the "social cost" of capital; likewise tax write-offs are excluded, since society ultimately bears the cost of pollution abatement. Thus, the costs reported show a total cost to society, which may not be borne directly by the industry.

The above methodology is applied to develop the costs for the larger portion of industry costs. Exceptions where exogenous cost data from economic studies have been accommodated have been mentioned before

Two other areas of costs are reported here which are developed on different bases. Costs to government are reported based on expenditures as scheduled in legislation. The costs of control of mobile sources (automobiles, aircraft, etc.) are not subject to the above methodology; their development is described within the text of Chapter 4.

1.3 FUTURE COSTS

The following paragraphs contain a discussion of the major areas of direction contained in the 1977 Amendments and indicate the types of costs that can be expected to be incurred in each case.

SIP REVISIONS - ATTAINMENT AND MAINTENANCE

Introduction

The Clean Air Act of 1970 provided for the establishment of National Ambient Air Quality Standards (NAAQS), including primary standards to protect public health and secondary standards to protect public welfare. Each state was required to submit for EPA's approval a State Implementation Plan (SIP), detailing the state's strategy for attaining and maintaining the NAAQS. Under the 1970 legislation, all states were to have attained primary standards by July 1, 1975, with a few exceptions where extensions were granted to mid-1977. Secondary standards were to be attained within a "reasonable time", usually the same time period as the primary standards.

The Clean Air Act Amendments of 1977 specify that in areas not attaining NAAQS, (nonattainment areas) the SIP's must now be revised and submitted to EPA for approval by July 1979. The revised plans are required to impose measures representing reasonably available control measures (RACM) on existing stationary sources and transportation strategies for mobile sources (such as inspection and maintenance programs) which levels of control take cost and other factors into account. For major new or modified sources, the revised plans must require lowest achievable emission rates (LAER). Other specific requirements are described below.

Nonattainment Areas

The 1977 Clean Air Act Amendments extended the statutory attainment dates to December 1982 for all pollutants. In the case of photochemical oxidants (ozone) and carbon monoxide, Congress recognized the difficulty that areas with problems dominated by automobile emissions would have in demonstrating attainment by the earlier date. In such cases, an additional five years, to 1987, may be permitted. If the additional five-year extension is needed, the state must submit a revised SIP in 1979 which demonstrates that attainment is not possible by 1982 despite the application of all reasonably available control measures. Extensions of attainment dates beyond 1982 require the implementation of an inspection/maintenance (I/M) program.

Where an extension has been granted, the state must adopt by 1982, the remaining enforceable measures necessary to attain standards for photochemical oxidants and/or carbon monoxide.

If a state is unable to submit an SIP that can demonstrate attainment of national standards and which can be approved by EPA, specific sanctions are invoked under the Act including no major source construction after July 1979 and restrictions on federal funds for highways and wastewater treatment facilities. A major source is defined as one which has the potential of emitting at least 100 tons of pollutants per year before controls.

Prior to attainment of standards, the Clean Air Act Amendments call for interim progress in emission reductions on an annual basis, which will provide for attainment by the statutory dates. There is an explicit requirement that to the extent possible these reductions should be realized in early years. Growth must take place within the framework of a plan which will achieve health-based standards:

Prior to July 1979, the EPA offset ruling is in effect. There are four key conditions to the offset ruling:

- For every ton of emissions from a new source, there must be an offsetting emission reduction for existing sources of greater than one ton;
- The new source must meet the lowest achievable emission rate (LAER) which is the lowest rate achieved in practice or the lowest emission limitation set forth by a SIP for that same class or category of sources;
- All existing major sources owned and operated in the same state by the firm operating the new source must be in compliance with the applicable emission limitations and standards, or be meeting the target dates of a compliance schedule; and

- These offsets must provide a positive net air quality benefit in the nonattainment area.

After July 1979, states are given a choice of two options as to how to handle new growth. The state can either:

- Create a quantitative margin for growth within the state implementation plan by imposing emission limitations on existing sources to a greater degree than minimally necessary to meet standards; or
- Continue some form of case-by-case emission offset approach.

In many cases the states will provide for a combination of both approaches. With either option new major sources must meet the lowest achievable emission rate.

Transportation Control Plans

The 1977 amendments to the Clean Air Act permitted a five-year extension of the 1982 deadline for achieving carbon monoxide and photochemical oxidant standards. This extension is contingent on a state demonstrating in its 1979 State Implementation Plan (SIP) that attainment is not possible by 1982 despite the implementation of all reasonable stationary and transportation control measures.

Most major urban areas with carbon monoxide and photochemical oxidant problems will be unable to meet the air quality health standards by 1982 through reliance on stationary source controls and federal new car standards alone. These areas therefore will be required to develop and implement such transportation strategies as mass transit improvements, preferential bus and carpool treatment, areawide carpool programs, parking management, pricing, auto-restricted zones, etc. — which are all designed to reduce auto emissions.

In order to achieve reasonable progress toward these standards, EPA is requiring the 1979 SIPs to demonstrate a commitment to (1) accelerated implementation of specific strategies (e.g., transportation improvements contained in the current or recent plans); (2) the incremental phase-in of additional strategies; and (3) a schedule of activities leading to implementation of an inspection/maintenance program by 1981 (decentralized system) or 1982 (centralized system).

Congress authorized $75 million in planning funds in the 1977 CAA Amendments. $50 million was appropriated in fiscal year 1979 to support the first year of the local planning process. The Department of Transportation also contributes funding for these grants to local governments. These funds are discussed further in the Cost to Governments Chapter.

Prevention of Significant Deterioration (PSD)

In 1972, the Sierra Club and other environmental groups filed suit against EPA for failure to promulgate regulations under the Clean Air Act to prevent the significant deterioration of air quality. Both the District Court of the District of Columbia and the U.S. Court of Appeals for the District of Columbia Circuit granted the Sierra Club's motion and required EPA to promulgate significant deterioration regulations. In June 1973, the Supreme Court, by a four-to-four vote, affirmed the judgement of the Court of Appeals.

After extensive public participation and technical and economic analyses, EPA published final regulations in December 1974 which are based on allowable increments of pollutant concentrations for specific categories of new major industrial sources under an area-classification procedure. Subsequently, the Administration, as part of the Energy Independence Act of 1975, requested Congress to consider legislation which would clarify Congressional intent on the prevention of significant deterioration of air quality. The Administration requested that Congress carefully examine the potential effects of a significant deterioration policy, including the consideration of its complete elimination as well as other alternative approaches. In addition, Congress was asked to provide guidance that would allow a balancing of environmental, economic, and energy concerns in any legislative determination of the significant deterioration issue.

The Clean Air Act Amendments

The 1977 Amendments adopted EPA's basic approach to PSD standards. Significant deterioration is prevented by establishing area classifications designed to correspond to the overall air quality intended for the area, and to reflect the amount of energy or industrial growth desired. Three "classes" were established as follows:

- Class I — Applies to areas in which practically any air quality deterioration would be considered significant, thus allowing little or no energy or industrial development.
- Class II — Applies to areas in which deterioration that would normally accompany moderate, well-controlled growth would not be considered significant.

- Class III — Applies to areas in which deterioration would be permitted to allow concentrated or very large-scale energy or industrial development.

All existing international parks, national wilderness areas, memorial parks larger than 5,000 acres, and national parks larger than 6,000 acres are designated Class I. These lands may not be redesignated into a different class. All other regions are initially designated as Class II. They may be redesignated by a state into either Class I or Class III, subject to various public hearing and analysis requirements.

Each class has maximum specified allowable increments of air quality deterioration. Major new and modified sources are subject to preconstruction review, and must meet New Source Performance Standards (NSPS). These sources must conform to Best Available Control Technology (BACT) requirements. Under EPA's proposed regulations, all new major stationary sources and modified sources commencing construction or modification after December 1, 1978, must conform to these standards.

New Source Performance Standards

The Amendments also clarify certain aspects of New Source Performance Standards which had previously been evolved by the Agency (e.g., clarification of the term "modification"), but most significantly set rather stringent rules regarding fossil-fueled sources. The Amendments essentially require the use of either coal cleaning or flue-gas desulfurization for all new sources. This limits the preferential use of low-sulfur coal, and should avoid any disruption of the potential supply of coal from various sources. The Amendments also specify that emission control strategies must be based on continuous control equipment rather than tall stacks or intermittent controls such as production cutbacks.

Visibility Goals

The 1977 Amendments speak to a new aspect of air pollution in that they call for the Agency to develop appropriate analyses, methods, and regulations to protect the condition of visibility from degradation by man-made air pollutants. This direction is applicable to Class I areas, e.g., national parks, etc.

Cost Implications

The discussion herein concerns the cost of implementing the policies and regulations for nonattainment areas and for PSD regulations. The discussion in general is qualitative in that specific cost figures are not presented. Cost data were not available for this study. Few if any of the respective state agencies have entered the cost-analysis phase. The task is complex and will require significant resources.

The cost of air quality attainment and maintenance measures can be divided into direct and indirect costs. Direct cost can be estimated with considerable accuracy.

The direct costs include all expenditures required of a source, such as investment and operating costs for control equipment, incremental costs of fuel switching, costs of production process changes, emissions monitoring costs, administrative costs for accounting and reporting, costs of supervision of operating personnel, and costs required of the governmental unit for implementing a measure, such as operating costs for permit review programs, monitoring of air quality, reviews of source emission reports, and source surveillance. Indirect costs include the effects on sectors of the economy that are not required to respond to a particular maintenance measure, such as price changes for materials or products, costs associated with changes in behavioral patterns, and costs of increased solid waste and water pollution control.

The following potential cost implications are noted:

1. For existing stationary sources, RACM requirements will vary from state-to-state, from region-to-region, and even from source-to-source. The requirements will allow for the retrofitting of existing processes, taking technological feasibility and cost into account.

2. For mobile sources, inspection and maintenance programs may be instituted in certain areas. This will involve additional costs to automobile owners (for maintenance) and to the municipal or state governments (for inspection). Such costs are expected to be minimal to the consumer.

3. Major new sources in nonattainment areas may have increased costs over NSPS or BACT costs in order to comply with the LAER requirements. Finally, depending on how the state allows for new growth, there may be additional costs associated with an offset market or other state-adopted growth programs.

4. "Major sources" as defined by the Clean Air Act Amendments is broadened to include all sources which "potentially" emit 100 tons per year or more of any pollutant. EPA has interpreted this to include sources whose emissions before controls would have been 100 tons. However, sources whose "allowable" emissions (after application of LAER) would be below 50 tons per year are not considered major sources. The effect of this change is to increase the number of sources covered by nonattainment and PSD regulations.

5. Under the PSD requirements, major new or modified sources may incur additional costs complying with BACT. The standards and associated costs will vary depending on the class designation of the region where the new source is locating.

THE COST OF CLEAN WATER

1. INTRODUCTION AND SUMMARY

PURPOSE AND SCOPE

Section 516(b) of the Federal Water Pollution Control Act amendments (PL92-500, hereafter FWPCA) of 1972 requires an annual report on the costs of meeting the provisions of that act; this report is submitted in response to these requirements.

Costs reported include those attributable directly to control measures (devices, process changes, etc.) and program costs for research, administration, enforcement at the Federal, state, and local levels. Sources of water pollution are broken down into industrial, municipal, and nonpoint categories, and direct control costs are estimated for these categories.

Industrial costs at the plant level are taken for the most part from the Effluent Guidelines Development Documents, which were prepared under Sections 304, 306, and 307 of PL92-500. These documents define the levels of pollutant removal that must be achieved by each industry category at the interim level, best practicable technology (BPT) to be achieved by July 1, 1977, and the final level, best available technology (BAT) to be achieved by July 1, 1983.

This report was prepared in 1978, and reflects the regulatory framework in existence early in 1978. Projections beyond past expenditures are subject to change. Significant changes in regulations will shortly affect the control technologies and associated costs.

The Clean Water Act of 1977 allows for less stringent controls for conventional pollutants. However, more stringent guidelines may result for the 21 industries covered by the 1976 Consent Agreement.

The magnitude of these changes will vary considerably on an industry-by-industry basis. An extreme example is the Explosives industry. The Cost of Clean Water estimates show slightly over $2 billion of investment from 1977-1986. Preliminary estimates emanating from the current BAT-review process indicate that new investment will be only about $3-4 million for this industry. While this is not representative of the magnitude of the changes to be expected, it does indicate the degree of uncertainty in the present estimates. *Therefore, the reader should keep in mind that the costs presented here represent what industries would have had to pay if the regulations in effect in early 1978 remained unchanged.*

Municipal costs are presented as total capital investment achievable under the existing and projected Federal contract authority (i.e., what will be spent rather than what is needed), as distinguished from the industrial costs, which are estimates of what will be required to achieve given control levels. This assumption is a recognition of the fact that the municipal needs are substantially in excess of available resources.

All abatement costs in this report are stated in July 1, 1977 dollars. Where costs were derived relative to another time period, these costs were updated using the implicit price deflater of the gross national product (Fixed non-residential investment part).

No measures have been promulgated by the agency that apply to the control of pollutants for non-point sources. A section of this report does discuss the problem of control of water pollution from non-point sources. Estimates of the costs for these controls assuming that the coals of PL 92-500 are applied to this category appear in Chapter 10.1. However, these estimates are not presented in the National totals.

This report does not attempt to include all costs associated with the reduction of the pollution of the Nation's waterways. Various state and local regulations, with associated costs, antedated Federal water pollution control regulations. Thus the costs described in this document are restricted to incremental costs, over and above any costs of control incurred on the level of control practiced prior to the FWPCA. Fiscal year 1972 is taken to be the baseline from which incremental costs were calculated.

Within this framework, the estimated direct costs and benefits of measures to control water pollution from industrial and other sources are calculated. Investment costs are projected through 1986.

Note that this report specifically does not dictate EPA policy with respect to the application of presently available or projected technology for the control of effluent quality to any industry or activity. Simplifying assumptions were required in order to estimate the effect of EPA Regulations on the industries included. The control technologies, or mix thereof, which were assumed in order to provide these estimates are neither specifically required by law nor by EPA; no contrary interpretation of the contents of this document should be made.

A uniform costing methodology has been applied to the industrial sectors incurring water pollution abatement costs. Being free of the requirements of macroscopic input-output models, this methodology permits examining each industrial sector at the most appropriate level of disaggregation and allows independent determination of industry growth. In addition, municipal charges have been included in a uniform manner which is consistent with Federal policy.

As a result of court action or industry objection some of the regulations proposed or promulgated under PL 92-500 have been withdrawn, suspended, or revoked. For the purposes of this report, with one exception, the assumption has been that the regulations were defective only in a technical sense and that similar regulations, incurring similar costs but possibly with differing standards for effluent quality, will be promulgated.

COSTS OF IMPLEMENTING THE ACT

Estimates of the capital investment and annualized costs required for implementing the FWPCA over the periods 1972-77, 1977-81 and 1977-86 and the year 1977 are summarized in Table 1-1. Each number in Table 1-1 is repeated within the appropriate chapter of this report where specific assumptions and background data are presented and discussed.

Table 1-1 does *not* include an estimate for the control of nonpoint sources. EPA has not yet issued regulations controlling nonpoint sources; and the control technology and degree of control is still uncertain. This report does contain a discussion of nonpoint sources (agriculture, silviculture, urban runoff and new construction runoff control) in Chapter 10.1. Preliminary estimates indicate that future investment needs will be about $58 billion in the next five years. No estimate is available on what portion of this investment need will actually be spent.

Environmental Expenditures of the United States Petroleum Industry 1970-1979

PUBLICATION NO. 4325
Based on a Survey Conducted by
The Environmental Affairs Department

INTRODUCTION

This is the tenth report on environmental protection expenditures of the petroleum industry within the United States prepared by the American Petroleum Institute's Environmental Affairs Department.

The same general format has been used for each of the surveys so that the annual expenditures for each reporting period could be compared with previous annual expenditures. It should be noted that each of the studies has had a slightly different reporting base, because the number of cooperating companies varied from survey to survey. The "totals" reported here are the sums of the expenditures reported to API rather than the total expenditures of the industry. The partial expenditures reported to API have not been extrapolated to represent 100% of the industry expenditures.

A facsimile of the questionnaire used in the survey is found in the back of this report.

It was developed after consultation with representatives of all petroleum industry disciplines and is similar to the questionnaires used in previous API surveys.

Instructions and guidelines assisted the respondents in calculating capital expenditures on environmental activities, although respondents were urged to report any available actual cost data. The guidelines covered all phases of industry operations and provided a uniform procedure for determining environmental expenditures.

These questionnaires were submitted to the corporate offices of the member companies of API and to members of the National Petroleum Refiners Association. The companies participating in the survey had approximately 70% of the total industry refining capacity.

As completed questionnaires were received, they were forwarded without identification by company to an independent organization for tabulation. The data contained in TABLES I through V were compiled by Deloitte Haskins & Sells, Washington, D.C.

The companies participating in this survey series have reported environmental expenditures of $17.9 billion for the 10-year period ending in 1979.

Environmental Expenditures Reported to API

TABLE I
SUMMARY TABULATION
(Millions of Dollars)

	YEAR										
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	TOTAL
TABLE II — TOTAL EXPENDITURES											
1. Air	$320	$571	$550	$737	$932	$1,039	$1,216	$1,188	$1,349	$1,616	$9,518
2. Water	259	415	379	402	530	629	822	950	884	1,061	6,271
3. Land and other	60	101	91	100	150	456	336	383	194	203	2,074
TOTAL	$639	$1,087	$1,020	$1,239	$1,612	$2,124	$2,374	$2,521	$2,427	$2,820	$17,863
TABLE III — CAPITAL EXPENDITURES											
1. Air	$181	$391	$305	$436	$527	$601	$536	$339	$429	$561	$4,306
2. Water	163	224	184	194	271	356	411	434	340	394	2,971
3. Land and other	34	57	51	52	97	396	269	184	89	92	1,321
TOTAL	$378	$672	$540	$682	$895	$1,353	$1,216	$957	$858	$1,047	$8,598
TABLE IV — ADMINISTRATIVE, OPERATING, AND MAINTENANCE EXPENDITURES											
1. Air	$108	$143	$ 198	$ 251	$ 352	$389	$635	$792	$864	$997	$ 4,729
2. Water	92	185	187	201	249	262	401	502	532	594	3,205
3. Land and other	24	41	37	43	50	55	63	197	101	106	717
TOTAL	$224	$369	$422	$495	$651	$706	$1,099	$1,491	$1,497	$1,697	$ 8,651
TABLE V — RESEARCH AND DEVELOPMENT EXPENDITURES											
1. Air	$ 31	$ 37	$ 47	$ 50	$ 53	$ 49	$ 45	$ 57	$ 56	$ 58	$483
2. Water	4	5	8	7	10	11	10	14	12	13	95
3. Land and other	2	3	3	5	3	5	4	2	4	5	36
TOTAL	$ 37	$ 46	$ 58	$ 62	$ 66	$ 65	$ 59	$ 73	$ 72	$ 76	$614

Environmental Expenditures
Reported to API

TABLE II
TOTAL EXPENDITURES
(Millions of Dollars)

	YEAR										
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	TOTAL
1. AIR:											
Capital	$181	$391	$305	$436	$527	$601	$536	$339	$429	$561	$4,306
Administrative, operating & maintenance	108	143	198	251	352	389	635	792	864	997	4,729
Research & development	31	37	47	50	53	49	45	57	56	58	483
TOTAL	$320	$571	$550	$737	$932	$1,039	$1,216	$1,188	$1,349	$1,616	$9,518
2. WATER:											
Capital	$163	$224	$184	$194	$271	$356	$411	$434	$340	$394	$2,971
Administrative, operating & maintenance	92	185	187	201	249	262	401	502	532	594	3,205
Research & development	4	6	8	7	10	11	10	14	12	13	95
TOTAL	$259	$415	$379	$402	$530	629	$822	$950	$884	$1,001	$6,271
3. LAND AND OTHER:											
Capital	$ 34	$ 57	$ 51	$ 52	$ 97	$396	$269	$184	$ 89	$ 92	$1,321
Administrative, operating & maintenance	24	41	37	43	50	55	63	197	101	106	717
Research & development	2	3	3	5	3	5	4	2	4	5	36
TOTAL	$60	$101	$ 91	$100	$150	$456	$336	$383	$194	$203	$2,074
4. AIR, WATER, LAND AND OTHER:											
Capital	$378	$672	$540	$682	$895	$1,353	$1,216	$957	$858	$1,047	$8,598
Administrative, operating & maintenance	224	369	422	495	651	706	1,099	1,491	1,497	1,697	8,651
Research & development	37	46	58	62	66	65	59	73	72	76	614
TOTAL	$639	$1,087	$1,020	$1,239	$1,612	$2,124	$2,374	$2,521	$2,427	$2,820	$17,863

Environmental Expenditures Reported to API

TABLE III
CAPITAL EXPENDITURES
(Millions of Dollars)

	YEAR										
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	TOTAL
1. AIR:											
Exploration & production	$ 9	$ 15	$ 17	$ 14	$ 27	$ 59	$ 85	$ 68	$ 59	$ 55	$ 408
Transportation	3	8	3	10	22	37	30	26	20	15	174
Marketing	54	39	21	43	105	55	36	15	18	43	429
Manufacturing	115	329	264	369	373	450	385	230	332	448	3,295
TOTAL	$181	$391	$305	$436	$527	$601	$536	$339	$429	$561	$4,306
2. WATER:											
Exploration & production	$ 74	$ 82	$ 68	$ 62	$ 92	$117	$135	$187	$206	$240	$1,263
Transportation	11	20	16	22	37	84	57	45	38	35	365
Marketing	8	10	14	17	19	25	16	13	13	19	154
Manufacturing	70	112	86	93	123	130	203	189	83	100	1,189
TOTAL	$163	$224	$184	$194	$271	$356	$411	$434	$340	$394	$2,971
3. LAND AND OTHER:											
Exploration & production	$ 15	$ 13	$ 22	$ 27	$ 38	$ 57	$ 70	$ 54	$ 59	$ 63	$ 418
Transportation	4	6	8	9	37	322	188	106	18	12	710
Marketing	10	11	14	8	6	4	3	3	4	3	66
Manufacturing	5	27	7	8	16	13	8	21	8	14	127
TOTAL	$ 34	$ 57	$ 51	$ 52	$ 97	$396	$269	$184	$ 89	$ 92	$1,321
4. AIR, WATER, LAND AND OTHER:											
TOTAL	$378	$672	$540	$682	$895	$1,353	$1,216	$957	$858	$1,047	$8,598

Environmental Expenditures
Reported to API

TABLE IV
ADMINISTRATIVE, OPERATING AND MAINTENANCE EXPENDITURES
(Millions of Dollars)

	YEAR										
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	TOTAL
1. AIR:											
Exploration & production	$ 6	$ 8	$ 8	12	$ 15	$ 20	$ 21	$ 28	$ 32	$ 35	$185
Transportation	6	6	3	4	3	7	16	11	12	12	80
Marketing	8	13	15	21	43	34	24	30	29	37	254
Manufacturing	88	116	172	214	291	328	574	723	791	913	4,210
TOTAL	$108	$143	$198	$251	$352	$389	$635	$792	$864	$997	$4,729
2. WATER:											
Exploration & production	$ 16	$ 84	$ 66	$ 69	$ 90	$ 87	$115	$141	$154	$173	$995
Transportation	18	21	15	16	25	28	46	37	36	35	277
Marketing	3	5	6	7	8	11	13	13	22	19	107
Manufacturing	55	75	100	109	126	136	227	311	320	367	1,826
TOTAL	$ 92	$185	$187	$201	$249	$262	$401	$502	$532	$594	$3,205
3. LAND AND OTHER:											
Exploration & production	$ 11	$ 16	$ 16	$ 20	$ 24	$ 29	$ 27	$ 31	$ 38	$ 36	$248
Transportation	4	5	9	8	8	8	14	128	24	18	226
Marketing	5	7	4	5	5	3	3	4	5	5	46
Marketing	4	13	8	10	13	15	19	34	34	47	197
TOTAL	$ 24	$ 41	$ 37	$ 43	$ 50	$ 55	$ 63	$197	$101	$106	$717
4. AIR, WATER, LAND AND OTHER:											
TOTAL	$224	$369	$422	$495	$651	$706	$1,099	$1,491	$1,497	$1,697	$8,651

Environmental Expenditures Reported to API

TABLE V
RESEARCH AND DEVELOPMENT EXPENDITURES
(Millions of Dollars)

	YEAR										
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	TOTAL
1. AIR:											
Product	$ 20	$ 22	$ 18	$ 19	$ 18	$ 15	$ 18	$ 24	$ 25	$ 21	$200
Process	10	14	26	29	33	32	25	30	28	34	261
Sampling & testing	1	1	3	2	2	2	2	3	3	3	22
TOTAL	$ 31	$ 37	$ 47	$ 50	$ 53	$ 49	$ 45	$ 57	$ 56	$ 58	$483
2. WATER:											
Product	$ 2	$ 2	$ 2	$ 1	$ 2	$ 3	$ 2	$ 4	$ 4	$ 3	$ 25
Process	2	3	4	4	7	6	7	6	7	9	55
Sampling & testing		1	2	2	1	2	1	4	1	1	15
TOTAL	$ 4	$ 6	$ 8	$ 7	$ 10	$ 11	$ 10	$14	$12	$13	$ 95
3. LAND AND OTHER:											
Product			$ 1	$ 1		$ 1	$ 1			$ 1	$ 5
Process	$ 2	$ 1	1	2	$ 2	2	2	$ 2	$ 3	3	20
Sampling & testing		2	1	2	1	2	1		1	1	11
TOTAL	$ 2	$ 3	$ 3	$ 5	$ 3	$ 5	$ 4	$ 2	$ 4	$ 5	$ 36
4. AIR, WATER, LAND AND OTHER:											
TOTAL	$ 37	$ 46	$ 58	$ 62	$ 66	$ 65	$ 59	$ 73	$ 72	$ 76	$614

The American Petroleum Institute
2101 L Street N.W.
Washington, D.C. 20037

August 25, 1980

Dear Sirs:

We have compiled the accompanying information (Tables I through V) from environmental expenditures survey questionnaires received directly by the American Petroleum Institute (API) and forwarded to us without identification (1972 through 1980) and from data taken directly from the API publication number 4176 entitled Environmental Expenditures of the United States Petroleum Industry 1966–1972 (1970 and 1971). Our procedures consisted of tabulating and summarizing the information received from the responses and publication number 4176 and making the necessary mathematical calculations as presented in the accompanying summaries. We cannot, of course, verify the accuracy of the information furnished to us.

Yours very truly,

Deloitte Haskins & Sells

APPENDIX
The Questionnaire

Instructions for Completing Questionnaire

American Petroleum Institute
Committee on Environmental Affairs

Environmental Expenditures
of the
United States Petroleum Industry

The accompanying questionnaire has been designed to obtain information which will be used to update the current API survey, "Environmental Expenditures of the United States Petroleum Industry."

American Petroleum Institute
2101 L Street, Northwest
Washington, D.C. 20037

Scope — Report all domestic environmental protection expenditures for the last full calendar year. Include all expenditures related to prevention, control, abatement or elimination of environmental pollution. Include expenditures which meet requirements promulgated by federal, state or local regulatory bodies or those which meet tax relief provisions, and those which qualify for industrial revenue bonding. The questionnaire includes three categories of such expenditures: (1) air, (2) water, (3) land and other. The latter includes expenditures for such items as solid waste management, noise abatement, and beautification where required by any authority. Do not include expenditures to meet OSHA requirements.

Confidentiality — Each questionnaire mailed to a member company will be treated as confidential. The original questionnaire will be returned to that company after its data has been tabulated.

Data — Report investment, administrative, operational and maintenance expense for environmental protection as reflected in your accounting records. Expense items may be estimated by allocation when actual records are not available.

Please report not only those "pollution abatement" expenditures which you report to the Department of Commerce (Bureau of Census Form MA-200 and Bureau of Economic Analysis Form BE-452A) but also those additional expenditures which have been made to modify products for environmental reasons.

To avoid the possibility of duplicate reporting of environmental expenditures on joint-interest properties, report Company *Net* Capital and Company *Net* Expense.

Criteria — Many expenditures cannot be attributed entirely to "environmental protection." In all such cases, appropriate consideration should be given to motivation: What were the principle factors involved in the expenditure decision? How large a role did considerations of environmental protection play in that decision?

Reported costs should not include the loss of revenue or estimates of business "loss" as a result of conditions associated with environmental protection.

Do include environmental protection costs of petrochemical or carbon black operations which are closely related to the basic petroleum operations, as in a combined refinery operation. Also include environmental protection costs of all other integrated functions of a petroleum operation. Non-petroleum operations (e.g., mining of coal, shale or minerals should not be included unless the objective of such activities is the extraction of gaseous and liquid hydrocarbons.

In some instances, estimates of environmental protection expenditures must be based on incremental concepts and will be heavily dependent on engineering judgment. For example, if a unit would meet good business operating requirements under normal design concepts, but requires modifications or additions because of environmental considerations, then the estimated cost of modifications or additions should logically be attributed to environmental protection. Other examples might include requirements for additional height on stacks, thicker walls on pipes or vessels, the inclusion of a vapor recovery system, or a smokeless flare. Investments which yield acceptable rates of return may logically be included as environmental expenditures, if, in fact, they meet the above mentioned criteria.

DETERMINING APPLICABLE EXPENSES

If administrative, operation and maintenance expense for environmental protection are not identified in your company records, these expense items may be estimated by allocation:

Assume that your environmental expenses (A) are related to total expenses (B) in the same proportion that your average gross fixed assets for environmental facilities (C) are related to your average gross fixed assets for total plant or division (D).

$$A = B \times \frac{C}{D}$$

If your company records do not provide appropriate estimates of environmental facility fixed assets, substitute capital expenditure data for fixed asset data.

Do not include depreciation in reporting current expenses. Do include corporate or central office salaries related to environmental protection, such as legal costs for assuring compliance with environmental regulations and the costs of a corporate Environmental Affairs Department. Assessments for accumulating spill cleanup funds or the expenses of maintaining a spill cleanup cooperative should be reported. Report costs of cleanup but not costs of associated fines.

When you determine your non-capitalized environmental expenses, you should include expenditures of the following types: economic baseline studies, pollution monitoring studies, historical site examinations, abandonment of facilities, restoration of sites, environmental impact statements, environmental assessments.

Use the net working interest only for joint properties in calculating operating and maintenance expenses.

RESEARCH AND DEVELOPMENT EXPENDITURES

Expenditures for research and development are seldom organized, reported, or budgeted in the same manner as capital expenditures. Some R & D expenditures are classified by research objectives, others are accumulated on a project-by-project basis. The following list is provided to serve as a reminder of the areas where the industry's R & D is frequently related to environmental protection objectives:

Air Conservation Expenditures

Product:	Process:
Motor Gasoline	Emission Reduction
Diesel Fuel	Vehicle Emissions
Jet or Turbo Fuel	Sampling and Testing
Distillate Fuel	
Residual Fuel	
Gaseous Fuels	

Water Conservation Expenditures

Process:

Emission Reduction
Sampling and Testing

Land, Noise and Other Conservation Expenditures

Process:

Emission Reduction
Sampling and Testing

CAPITAL EXPENDITURES

The lists which follow illustrate the types of capital expenditures which may be fully or partially attributed to environmental protection. For uniformity in reporting, please use the suggested percentage of total cost when you allocate expenditures to environmental protection. The lists are not inclusive. You may and should report environmental protection expenditures even if they are not listed. In all cases, include increased incremental costs resulting from environmental considerations—such as thicker walls for pipes and vessels.

The capital guidelines which follow are not intended to preclude the use of actual cost data where such information is available.

Capital Guideline Index

Manufacturing .... Pages 4 & 5
Exploration and Production .... Page 6
Transportation .... Page 7
Marketing .... Page 8

Capital Item Guidelines

MANUFACTURING *Air*	% of TOTAL COSTS
1. Bag filters	100
2. Cat cracking	10-20
3. Closed pressure and relief valve systems	100
4. CO boilers	50
5. Coke pilehousing	100
6. Covers on API separators	100
7. Crude or residual desulfurization	100
8. Cyclones (25% on fluid units)	25-100
9. Dust supression systems	100
10. Electrostatic precipitators	100
11. Emission and ambient air monitors	100
12. Environmental monitoring & sampling equipment	100
13. Extra tall stacks (20% for 200's; 30% for 300', etc.)	10-70
14. Flare gas recovery systems	75
15. Flare system	50
16. Floating roof tanks (new construction)	20
17. Floating roof tanks (conversion to)	100
18. Fuel gas desulfurization (Amine, etc.)	100
19. Hydrocracking	10-30
20. Hydrodesulfurizers	50
21. Incineration of waste gases	100
22. Increased processing for lead reduction	100

	% of TOTAL COSTS
23. Leak detection systems	100
24. LPG odor control facilities	100
25. Odor control	100
26. Regenerative caustic systems with sulfur recovery (Merox, etc.)	75
27. Smoke control of fired heaters	100
28. Smokeless flare systems	100
29. Sour H_2O stripper O.H. recovery facilities	100
30. Sulfuric acid plant	35
31. Sulfur recovery plants	100
32. Vapor recovery systems	100
Water	
1. Activated carbon absorption	100
2. Activated sludge plants	100
3. Air cooling	20-40
4. Air flotation	150
5. API separator	50-100
6. Ballast & slop treatment facilities	100
7. Clarification	100
8. Collection systems — separate sewer, etc.	100
9. Cooling towers	50-100
10. Deep well disposal	100
11. Environmental monitoring & sampling equipment	100
12. Flocculators	100
13. Oil recovery and handling systems	100
14. Oxidation ponds and mechanical aerators	100
15. Sanitary systems	100
16. Sludge farming	100
17. Sour H_2O strippers and/or oxidizers	50
18. Spent caustic treating systems	100
19. Spill booms and other spill cleanup equipment	100
20. Tank bottom disposal & treatment facilities	100
21. Trickling filer plants	100
22. Toxic waste disposal	—
Land and Other	
1. Noise reduction	100
2. Building aesthetics and landscaping	50
3. Environmental monitoring & sampling equipment	100
4. Equipment noise insulation	100
5. Fire walls or tank dikes	100

	% of TOTAL COSTS
6. Incinerators	100
7. Land restoration, revegetation, etc.	100
8. Landscaping	100
9. Mufflers	100
10. Sanitary land fills	100
11. Screening or buffering	100
12. Solid waste hauling & disposal equipment	100

EXPLORATION AND PRODUCTION
(Note: Gas processing plants should be reported if operated by production, but the manufacturing guidelines should be used.)

Air

1. Environmental monitoring and sampling equipment	100
2. Flare systems	50-100
3. Gas well and gas line automatic shut down devices	50-100
4. Odor control	100
5. Smokeless flare & smokeless burn pit systems	100
6. Sulfur recovery plants and H_2S controls	50-100
7. Vapor conservation equipment (tank & vent-line valves, etc.)	50-100
8. Vapor recovery systems	50-100

Water

1. Approved collection pits	100
2. Environmental monitoring and sampling equipment	100
3. Increased platform, drilling and completion costs to comply with Gulf Coast OCS Orders 5,7,8,9, and similar regulations	100
4. Salt water disposal (Do not include secondary recovery investments)	100
5. Sanitary sewage systems	100
6. Spill booms and other spill cleanup equipment	100
7. Surface casing	30-100
8. Tank bottom disposal and treatment facilities	100
9. SPCC Plan Requirements	100

Land and Other

1. Building aesthetics and landscaping	50-100
2. Control devices on onshore leases (check valves, hi-level shut down, hi-lo pressure, etc.)	100

	% of TOTAL COSTS
3. Drilling mud disposal	50-100
4. Elimination of pits and cellars (include cost of steel tankage if required)	100
5. Environmental monitoring and sampling equipment	100
6. Equipment noise insulation	100
7. Fire walls or tank dikes	100
8. Incinerators	100
9. Land restoration, revegetation, etc.	100
10. Investment for noise reduction	100
11. Radio alarm systems	10-50
12. Sanitary land fills	100
13. Solid waste disposal	100
14. Waste lubricant disposal	100
15. Historical site protection	100

TRANSPORTATION

Air

1. Environmental monitoring and sampling equipment	100
2. Floating roof tanks (new construction)	20
3. Floating roof tanks (conversion to)	100
4. Microballoons	100
5. Odor control	100
6. Smoke control (trucks, tank ships)	100
7. Vapor recovery systems	100

Water

1. Aerial and ground pipeline patrol equipment and related communications equipment	50-100
2. Ballast and stop reception/treatment for tank vessels	100
3. Cathodic protection of pipelines	50
4. Cathodic protection surveys	50
5. Cooling towers	50
6. Double bottoms or segregated ballast on tank vessels	100
7. Environmental monitoring and sampling equipment	100
8. Ground bed replacement for cathodic protection systems	50
9. Leak detection surveys (all types)	50
10. Mechanical seals on pumps	10
11. Oil/water separators & oil monitors	100
12. Oil/water separators	100
13. Pipeline reconditioning	50
14. Pipeline replacement	50

	% of TOTAL COST
15 Pipeline reroute (pollution prevention)	50
16 Pumpout systems	50
17 Replacement of pipeline river crossings	50
18 Replacement of wooden station platforms with concrete	50
19 Sanitary sewerage systems	100
20 Spill booms and other spill cleanup equipment	100
21 Spoil disposal from dredging operations	50-100
22 Tank bottom disposal and treatment facilities	100
23 Tank farm skimming ponds	100
24 Tank stripping eqpt. on tank vessels	50-100
25 SPCC plan requirements	100
Land and Other	
1 Noise reduction	100
2 Building aesthetics and landscaping	50
3 Environmental monitoring & sampling equipment	100
4 Fire walls or tank dikes	50-100
5 Incinerators	100
6 Land restoration, revegetation, etc.	100
7 Landscaping	100
8 Sanitary land fills	100
9 Solid waste hauling & disposal equipment	100
MARKETING	
Air	
1 Additional facilities	
a. Additional dispensing pump and auxiliary equipment	100
b. New storage	100
c. No-lead gasoline (third grade, low-lead gasoline)	100
2 Bottom-fill loading and vapor collection lines on trucks and tank cars	50
3 Environmental monitoring and sampling equipment	100
4 Evaporation control (Product storage and transfer to service stations)	100
5 Floating-roof tanks (conversion to)	100
6 Floating-roof tanks (new construction)	20
7 Gasoline volatility control:	
a. Additive facilities for segregated storage (such as New York City)	100
b. Auxiliary equipment	100
8 Odor control	100

9.	Vapor balancing systems	100
10.	Vapor recovery systems	100

Water

1.	Environmental monitoring & sampling equipment	100
2.	Control of effluent discharge at terminals	100
3.	Product recovery at bulk terminals	100
4.	Product spill prevention activities at bulk terminals	100
5.	Product spill prevention activities at terminals as required by government regulations	100
6.	Sanitary sewerage systems	100
7.	Waste product recovery or recycle	—
8.	SPCC plan requirements	100

Land & Other

1.	Noise reduction (baffles and insulation)	100
2.	Building aesthetics	50
3.	Environmental monitoring & sampling equipment	100
4.	Fire walls or tank dikes	100
5.	Incinerators	100
6.	Land restoration, revegetation, etc.	100
7.	Landscaping	100
8.	Mufflers	100
9.	Sanitary land fills	100
10.	Solid waste hauling and disposal equipment	100

SELECTED READINGS

IMPACT ASSESSMENT

THE MACROECONOMIC IMPACT
OF FEDERAL POLLUTION CONTROL PROGRAMS
1981 ASSESSMENT

SUBMITTED TO THE ENVIROMENTAL PROTECTION AGENCY

DATA RESOURCES, INC.

JULY 14, 1981

INTRODUCTION

This study presents an analysis of the macroeconomic impacts of federal air and water pollution control regulations on the United States economy.[1] The study does not include the value of improvements in the quality of life which are not priced by the market system. The analysis uses Environmental Protection Agency (EPA) estimates of the incremental costs of federal pollution control regulations for the period 1970-1987. For each industry, estimates were made for the capital investment, annualized capital costs, and operating and maintenance costs by industry. Estimates were also made of the costs of state and local governments' pollution control activities, and the cost to consumers and business of mobile source regulations. The estimates reflect only the "incremental" costs, i.e. the additional costs incurred solely as a result of federal regulations. Those additional costs which would have been undertaken in the absence of federal regulations are included in the macroeconomic "without" scenario (described below).

The analysis used the Data Resources, Inc. (DRI) macroeconomic model of the U.S. economy and covered the period 1970-1987. The analysis compared what economic conditions would have been without the costs of federal regulations to what economic conditions would have been with the costs of federal regulations. A baseline simulation, representing the performance of the economy under current EPA regulations, was constructed using the actual data for 1970-1980 and the TRENDLONG02S1 forecast for 1981-1987. This baseline simulation is called the "with" pollution control costs scenario. Appropriate adjustments were made to the "with" simulation to remove the incremental costs of federal pollution control. This simulation is called the "without" pollution control costs simulation. A comparison of the "with" and "without" simulations gives an assessment of the direct and indirect macroeconomic effects of federally induced pollution control costs on economic performance. Because the loss of benefits which results from removing regulations is not considered in this study, the results presented here cannot be taken as indicative of what would actually happen if regulations were to be removed.

---

[1] This study updates a previous DRI study, "The Macroeconomic Impact of Federal Pollution Control Programs-1979 Assessment."

To supplement this "base-case" analysis, three other simulations were performed. The first additional simulation analyzed the macroeconomic effects of possible government efforts to offset the effects of federal incremental costs of pollution control by pursuing a non-accommodating monetary policy. The second and third simulations analyzed the effects of incremental costs being either higher or considerably lower respectively than estimated in the original "with" case.

PRINCIPAL CONCLUSIONS

The incremental costs from Federal pollution control regulations have had four major effects.

1. Price increases are moderately higher. The costs per unit of output are raised by the federal regulations and these higher costs are eventually translated into higher prices. For example, the average annual rate of increase in the consumer price index (CPI-U) is 0.4 percentage points higher over the period 1970-1987 than would be the case in the absence of environmental regulations. The average annual rates of increase in the Producer Price Index (PPI) and GNP deflator are 0.5 and 0.4 percentage points higher, respectively, over the same period.

2. Until 1977, the real level of economic activity, as measured by gross national product, is stimulated by the incremental investment required under federal regulations and the additional activity generated by industries producing pollution control plant and equipment. In 1972, real GNP increases $9.2 billion or 0.5%. After 1979, the real level of economic activity declines as the higher price level reduces aggregate real output. Over the period 1970-1987, the average annual rate of growth of real GNP is reduced by 0.1 percentage point. Real GNP in 1987 is $21.8 billion or 0.7% lower.[2]

3. Employment is stimulated throughout the 1970-1987 period. Jobs are created in the pollution control equipment industry and in all industries to operate and maintain pollution equipment and facilities. The unemployment rate is on average 0.3 percentage points lower over the period. By 1987, there is a net increase of 524,000 additional jobs as a result of pollution controls.

4. Real business fixed investment is stimulated by the incremental investment mandated under federal regulation and by the additional activity generated by industries producing pollution control plant and equipment. In 1973, real business fixed investment is up $6.0 billion or 2.6%. Eventually, the combined effects of higher prices, increased interest costs, and reduced aggregate demand dampen investment spending. By 1987, real business fixed investment is only $0.9 billion or 0.3% higher.

IMPACT ON PRICES

In reducing pollution, the incremental costs from Federal regulation impose higher costs on firms and are passed through as higher product prices. The higher costs stem from two sources: first, labor and materials costs per unit of output are raised, as the additional labor and material inputs needed to operate and maintain pollution control equipment generate no additional output in a form measurable by the national income accounts. Second, the investment needed to produce a given level of output is raised, as the incremental investment costs produce no additional "measured" output. By 1987, the GNP deflator is 7.4% higher, raising its average annual rate of increase by 0.4 percentage point per year. Consumer prices, as measured by the consumer price index, are 6.6% higher, raising their average annual rate of increase 0.4 percentage point per year. Wholesale prices, as measured by the PPI, are 9.0% higher, raising their average annual rate of increase 0.5 percentage point.

The effect on prices rises over time, as the incremental costs of federal regulations rise rapidly. From 1980 to 1987, real incremental costs from federal regulations rise 48%, while real GNP in the "with" case rises 21%.

---

[2] Unless otherwise noted, all figures in real terms are expressed in constant 1979 dollars. All price indexes are based as 1979=1.

IMPACT ON REAL OUTPUT

The impact on real output varies over time. Initially, the incremental costs from federal regulations stimulate the economy. Increased operating and maintenance costs require extra workers and materials, and increased costs for pollution control plant and equipment represent increased demands on the industries that build them. Eventually, given the assumptions that profit margins are not reduced, firms pass on the full amount of higher costs into higher product prices, which dampen aggregate demand and counteract the initial stimulus.

Until 1980, real GNP is higher in the "with" case. The positive gap peaks in 1972, with real GNP up $9.2 billion or 0.5%. During the 1973 boom period and the subsequent downturn, this positive gap narrows significantly. Higher prices due to incremental costs reduce consumption spending and exports and raise imports. Incremental costs drive up unit costs of output, reducing productivity and aggregate supply. This drag on economic growth caused by pollution control costs is magnified over time. By 1987, real GNP is $21.8 billion or 0.7% lower.

IMPACT ON EMPLOYMENT AND PRODUCTIVITY

The incremental costs from federal pollution control regulations stimulate employment. Production, installation, and maintenance of pollution control plant and equipment creates jobs. However, this additional labor input does not generate additional measured output. In addition, productive capital per worker is lower, as the capital stock is diluted with the portion of capital required to control pollution. As a result, productivity growth declines on an average annual basis of 0.1 percentage point, as more resources are needed to produce the same amount of output. However, the employment required to comply with EPA's regulations is estimated to make the unemployment rate is 0.3 percentage point lower in the "with" case. By 1987, there are 524,000 additional jobs as a result of pollution control requirements.

BUSINESS FIXED INVESTMENT

Initially, incremental costs from federal pollution control regulations stimulate real business fixed investment. Firms require additional pollution control plant and equipment to meet federal standards. This boosts not only their own investment but also investment by firms that produce the pollution control plant and equipment. The stimulative effect peaks in 1973, with real business fixed investment up $6.0 billion, or 2.6% above what it would have been without federally required pollution controls. The stimulative effect tapers off as higher prices drive up interest rates and reduce aggregate demand. By 1987, real business fixed investment is $0.9 billion or 0.3% higher.

Investment for pollution control plant and equipment tends to reduce other kinds of investment, including housing. The degree of reduction varies with economic conditions and increases as the economy approaches full employment.[3] At full employment, mandated investment is assumed to replace other investment on a dollar-for-dollar basis. While total investment is higher, real "productive" business fixed investment (defined as total real business fixed investment minus real business fixed investment for pollution control) is lower in the "with" case. By 1987, real productive business fixed investment is $13.9 billion or 4.0% lower.

HOUSING

The slowdown in aggregate demand and incomes, combined with higher interest rates, reduces housing starts. The reduction, as measured by the differential between the two simulations, exhibits a very mild cyclical pattern. By 1987, housing starts are 115,000 units or 5.2% below the "without" case.

ESTIMATES OF INCREMENTAL POLLUTION CONTROL COSTS

The estimates of incremental pollution control costs from federal regulations were made by the EPA. The historical estimates are consistent with estimates collected and developed by the Census Bureau of the Department of Commerce. Incremental pollution control costs include only those costs as a result of federal air and water control requirements. They were broken down by 18 categories: 16 industrial categories, state and local municipal wastewater treatment facilities, and mobile source emissions.

---

[3] The critical assumptions of the basic analysis are described below, in the section entitled, "The Underlying Economic Path-The "With" Scenario."

The estimates were further broken down into incremental operating and maintenance costs, and incremental investment costs. Incremental operating and maintenance costs are the labor and material costs associated with operation and maintenance of pollution control plant and equipment. Incremental investment costs are the purchases of pollution control plant and equipment.

The EPA estimates of incremental costs are given in Tables 1 and 2. Total incremental costs rise from $6.4 billion (1979 dollars) in 1970 to $44.9 billion in 1987, an increase of 12.1% per year. Incremental operating and maintenance costs rise from $3.0 billion in 1970 to $24.8 billion in 1987, an increase of 13.2% per year. Incremental investment rises from $3.4 billion in 1970 to $20.0 billion in 1987, an increase of 11.0% per year. As a percent of total plant and equipment investment (in current dollars), incremental investment rises from 1.5% in 1970 to a peak of 3.9% in 1984 and falls to 3.4% in 1987.

THE UNDERLYING ECONOMIC PATH—THE "WITH" SCENARIO

The impact of pollution control costs depends upon the underlying state of the economy. The analysis covers the period 1970-1987, which contains many variations in the pace of economic activity and rate of inflation. The historical period (1970-1980) begins with the 1970 recession, in which real GNP dropped by 0.2%. The recovery began in late 1970. By 1973, the economy was booming and was operating at or near full employment. The recovery came to a halt due to a variety of factors--quadrupling of crude oil prices by OPEC, large increases in farm prices due to poor harvests worldwide, inflationary pressures emanating from the strong growth in the U.S. and elsewhere, the abandonment of wage and price controls, and a slowdown in monetary growth by the Federal Reserve, designed to reduce inflation. The economy began to recover in late 1975, and the recovery lasted until early 1980. Economic growth plunged in mid-1980 but recovered quickly in the latter half of the year. However, the rate of inflation remained very high by post-war standards.

The forecast period 1981-1987 is consistent with DRI's long-term trend simulation TRENDLONG0281. The recovery begun in 1980 continues, but is weak by historical standards. Continual increases in real oil prices, low growth in the labor force due to demographic factors, a monetary stance which remains tough on inflation, and general uncertainty about the economy contribute to slow growth. The forecast of a near full-employment economy in 1987 serves to maximize the effect of pollution controls on the price level. The rate of inflation unwinds slightly as the economy is assumed not to suffer from external price shocks i.e., abrupt changes in food and fuel prices are not projected to occur. Both the historical and forecast periods incorporate the full costs of pollution control. As such, they define the "with" scenario.

The major assumptions in the basic analysis that define the "with" scenario in the period 1981-1987 are:

- Energy Prices--prices of foreign crude oil will increase about 3% per year in real terms relative to wholesale prices.
- Monetary Policy--the money supply (M1B) will increase about 6% per year.
- Tax Policy--legislation will be enacted that results in a one-time reduction of 40% in effective asset lifetimes; the Kemp-Roth proposal to reduce personal income tax rates will be phased in during the 1981-85 period.
- Federal Spending--federal spending will be very tight, increasing only about 2% per year in real terms.
- Demographics--there will be slowing in the rate of increase in the labor force, due to the maturation of the baby boom.

DIRECT CHANGES TO REMOVE INCREMENTAL POLLUTION CONTROL COSTS--THE "WITHOUT" SCENARIO

A number of changes were made to the "with" scenario to remove the incremental costs of federal pollution control regulation (thereby defining the "without" scenario). A brief list of these changes is given below.[4] A more detailed explanation of these changes is given in the technical appendix.

---

[4] These adjustments take no account of the loss of benefits which would occur if the regulations were removed.

1. Plant and equipment investment by industry was decreased by the amount of the incremental investment costs estimated by EPA.

2. The cost of new investment was lowered as firms now need to invest less to produce a given amount of output.

3. Since many pollution control investments can be financed less expensively in municipal bond markets, financing costs were raised slightly.

4. Prices by industry were reduced to reflect decreased production costs, as less labor and material are needed to produce a given level of output. These reduced costs were passed through into lower product prices according to a simple model of industrial price determination constructed for this study.

5. Employment was reduced since the workers required to produce, install and maintain pollution control plant and equipment would no longer be needed.

6. As the federal government makes grants-in-aid to state and local governments to construct municipal waste water pollution control facilities, grants-in-aid were reduced by amounts estimated by the EPA.

7. Prices of new motor vehicles were reduced to incorporate the reduced costs of emission control devices.

8. Investment by firms to purchase new vehicles was reduced to reflect the reduced costs of emission control devices.

9. Consumer expenditures for vehicle maintenance were reduced to incorporate the lower costs for maintaining emission control devices.

10. Consumer expenditures for gasoline were reduced as vehicles would achieve higher mileage without emission control devices.

ECONOMIC IMPACTS—FURTHER DISCUSSION

The economic impacts of incremental pollution control costs from federal environmental regulations are discussed by sector. The economic impacts are drawn up by comparing the "without" scenario--a simulation without the incremental costs--to the "with" scenario--a simulation with the incremental costs.

PRICES

The incremental costs of federal pollution control raise the rate of price increase in three ways.

1. The operating and maintenance costs raise the unit cost of output. A firm now requires additional labor and materials to produce a given level of output. A firm is producing a joint product of its output and a cleaner environment, although the benefits from the cleanup are not incorporated in this analysis.

2. Incremental investment costs raise the capital cost per unit of output. A firm's capital is diluted by the portion required to control pollution rather than produce output.

3. Incremental investment needed to meet the federal regulations increases demand on the industries supplying those investment goods and their suppliers. The impact on prices depends on underlying economic conditions. The impact is accelerated in the 1972-1973 and 1977-1979 boom periods, when the economy was already experiencing price pressures.

Initially, incremental pollution costs reduce corporate profits, until firms can pass these added costs into higher product prices. The speed of this pass-through was determined on an industry-specific basis, using a simple model relating prices to unit costs, productivity, and capacity utilization. Labor productivity declines for two reasons. First, more workers are required to produce a given level of output, as some workers operate and maintain the pollution control equipment. Second, productive capital per worker is lower, as the capital stock is diluted with the portion of capital required to control pollution. Productivity is 0.3% lower in 1980 and 0.9% lower in 1987. Productivity growth falls 0.1 percentage point per year on average over the entire period.

The impact on the rate of price increase is noticeable, given the increases in unit costs, reduced productivity, and added demand pressures. The producer price index is 4.1% higher in 1980 and 9.0% higher in 1987. The average annual rate of change in producer prices is raised 0.5 percentage point over the period 1970-1987. The effect on consumer prices is smaller, with their average annual rate of change increased 0.4 percentage points per year.

BUSINESS FIXED INVESTMENT

The incremental investment costs to industry (excluding state and local costs and mobile source costs) rise from $2.9 billion in 1970 to $7.6 billion in 1980. The costs peak at $11.9 billion in 1986 and fall slightly to $11.6 billion in 1987. Over the historical period 1970-1980, incremental investment costs average 2.4% of total plant and equipment investment. Over the forecast period 1981-1987, this ratio averages 3.6%.

Incremental investment costs increase total business fixed investment. Incremental investment represents increased demands on industries that produce pollution control plant and equipment. These increased demands generate additonal output and employment which in turn increased investment. Business fixed investment rises, with the peak stimulative effect occurring in 1973, up $6.0 billion or 2.6% from those levels that would otherwise have occurred. Eventually, higher rates of price increase drive up interest rates and reduce demand so that in 1987, investment is up only $0.9 billion or 0.3%.

The effect on "productive" (excluding pollution control) investment is more pronounced. Incremental investment costs raise the effective cost of investment. More investment is now required to produce a given level of output, causing firms to require a higher rate of return from productive investment. This increased rate of return depresses investment. The negative impact of a higher required rate of return (as well as reduced aggregate demand and higher interest rates) is greater than the positive stimulus to investment from the incremental costs. By 1987, productive investment is $13.9 billion or 4.0% lower.

INTEREST RATES

Incremental pollution control costs raise interest rates significantly, as investors require higher nominal interest rates to compensate them for the costs of lending that stem from higher price increases. Interest rates increase steadily as prices rise. Higher prices also generate an eventual reduction in real activity, which reduces pressures on interest rates as loan demands subside. For example, the increase in the federal funds rate peaks at 1.87 percentage points in 1982 and declines to 0.80 percentage point in 1987. Interest rates do rise more than enough to cover the price increases so that, in general, real interest rates are higher.

HOUSING

Higher interest rates drive down business fixed investment and reduce housing activity. Housing starts are lower in every year, but the decline varies over time. In 1979, near the end of the economic expansion, housing starts are 88,000 units or 4.3% lower. In 1987 when the economy is approaching full employment, so that competing investment demands dry up traditional mortgage funds, housing starts are lower by 115,000 units or 5.2%.

CONSUMER SPENDING

Initially, real consumer spending rises because of incremental costs of emission controls to meet federal regulations. Vehicle emission controls increase maintenance expenditures and, (because fuel consumption is increased), gasoline purchases rise; they also increase car prices, which tends to drive down vehicle purchases. Secondary effects from increased activity in firms producing pollution control plant and equipment and their suppliers also tend to raise consumer spending initially . However, by 1977, consumer spending falls in response to higher prices and interest rates. By 1987, consumer spending is $18.7 billion or 1.0% lower. Purchases of motor vehicles and parts are particularly hard hit, down $7.0 billion or 5.8%. The only consumer spending categories still higher in 1987 are gasoline and transportation services (maintenance expenses).

GOVERNMENT

FEDERAL

In this analysis, federal expenditures are assumed to be constant in real terms. This means that the federal government maintains a specific level of services and adjusts the dollar level of spending in response to changing price levels. For this reason, nominal expenditures are higher because prices are higher. Receipts are also higher, but by a smaller amount, as the higher price level boosts nominal incomes and taxes. Initially, real incomes are also higher, due to the increased economic activity which further boosts tax receipts. However, the net effect on the federal deficit is negative after 1974. By 1987, the deficit is $10.2 billion larger in current dollars.

STATE AND LOCAL GOVERNMENTS

Federal regulations require state and local governments to construct waste water treatment facilities. Seventy-five percent of construction costs are funded from federal grants-in-aid. However, the state and local governments are responsible for the higher operating and maintenance costs associated with these facilities and for municipal air pollution control costs. The net effect of pollution control requirements is a slight increase in real spending. In 1987, real purchases are $1.2 billion, or 0.4% higher.

FOREIGN TRADE

Higher pollution control costs increase domestic prices, which reduce real exports and raise real imports. The initial stimulus to aggregate activity drives up imports, but, eventually, as economic activity declines, imports also decline. In 1973, real imports are $2.4 billion (or 1.2%) higher, but by 1987, they are $3.7 billion or 1.1% lower. The stimulative effect on real exports is mild, with real exports down by $0.4 billion or 0.2% in 1974. After that, exports are higher as foreign economy activity does not decline as much as in the U.S. In 1979, real exports are $1.3 billion, or 0.4% higher. The situation reverses again in 1986, as the greater domestic price increases drive down exports. By 1987, real exports are $2.0 billion, or 0.5% lower. The net effect on the current dollar trade balance is mildly negative until 1982; after 1982, the effect is positive but becomes negative in 1986. By 1987, the current dollar trade balance is $1.9 billion lower.

CONCLUSION

The principal results of this analysis are given below and are summarized in Table 3.

1. The average annual rate of increase in consumer prices rises 0.4 percentage points in the period 1970-1987 as firms pass on the higher costs of pollution control.

2. Until 1980, the real level of GNP is higher, stimulated by the federally mandated incremental investment and operating and maintenance costs and by the additional activity in industries supplying pollution control plant and equipment. In 1972, real GNP is $9.2 billion or 0.5% higher. After 1979, real GNP declines in response to the higher price level. By 1987, real GNP is $21.8 billion or 0.7% lower. The average annual rate of growth of GNP is reduced 0.1 percentage point.

3. Employment is stimulated throughout the 1970-1987 period as jobs are created in industries to operate and maintain pollution control plant and equipment and in the pollution control plant and equipment (supplier) industry. In general, the unemployment rate is 0.3 percentage points lower, and by 1987 there are 524,000 net additional jobs as a result of pollution controls.

4. Business fixed investment is stimulated by the incremental investment mandated by federal regulations and the additional activity generated in industries that produce that pollution control plant and equipment. In 1973, real business fixed investment rises by $6.0 billion, or 2.6%. Eventually, the combined effects of higher prices, increased interest costs and reduced aggregate demand dampen investment spending. By 1987, real business fixed investment is only $0.9 billion or 0.3% higher.

SENSITIVITY ANALYSIS

Three alternative simulations were performed. The first two simulations analyze the effects of slightly higher or considerably lower mandated pollution costs. The third simulation analyzes the effects of a monetary policy that attempts to neutralize the money supply increases induced by pollution control costs.

Case 1: Higher Pollution Control Costs

The base case "with" simulation included certain recently announced reductions in municipal wastewater treatment construction grants and mobile source emissions control costs. The "with high" pollution control cost simulation includes those costs. In 1981, these higher costs add $861 million (or 2.5%) to the mandated incremental costs. By 1987, they add $2659 million (or 5.9%) (Tables 4 and 5). The total increase in incremental costs from 1979 to 1987 is $12.6 billion or 2.6%. The results from the "with high" simulation are very similar to the "with" base case results, and are shown in Table 7.

Case 2: Lower Pollution Control Costs

A second simulation was constructed to examine the macroeconomic effects of future incremental pollution control costs being much lower than those used in the "with" base case simulation. This was called the "with low" simulation, in which a gradual tapering off of incremental costs by 10% per year beginning in 1981 was assumed. By 1987, total incremental costs had fallen to $13.5 billion or 30% of the base case analysis estimates (Tables 4 and 5). The total reduction in incremental costs is $117.0 billion, or 23.8%. The results are compared to the "with" base case simulation in Table 8.

A decline in future real incremental costs reduces the effects of pollution control on prices. By 1987, the level of the implicit price deflator has fallen 0.9% relative to the "with" base case, and its annual rate of change has fallen to 7.7% per year. This decline in incremental costs removes only 15% of the price effects of pollution control costs.

The effects on real GNP are less pronounced. Initially, reduced incremental costs reduce real GNP. Reduced operating and maintenance costs require fewer workers and materials and decreased investment costs represent a decrease in demand on those industries that produce pollution control capital. Eventually, firms pass on the full amount of these lower costs as lower product prices, which stimulate aggregate demand and counteract the initial output reduction. By 1987, real GNP is $1.6 billion higher, while the unemployment rate remains 0.3 percentage points higher. Business fixed investment is down $5.6 billion or 1.6% in 1987, while productive investment is $4.5 billion, or 1.4% higher.

Case 3: Non-Accommodating Monetary Policy

The increase in nominal GNP due to pollution control costs implies an increased transactions demand for money. The money supply in the base case analysis increases to accommodate this higher transactions demand. A simulation was constructed in which the money supply does not accommodate this increased demand. Rather, nonborrowed reserves, the main policy lever of the Federal Reserve Board, are reduced in order to hold the money supply (as defined as M1-B) to its level in the "without" simulation (Table 6). This simulation is called "offset" and is compared to the base case simulation in Table 9.

Non-accommodating monetary policy dampens aggregate demand by raising interest rates and depressing interest sensitive sectors of the economy such as housing. By 1987, real GNP falls $9.3 billion or 0.3%, and the unemployment rate is 0.1 percentage point higher. Business fixed investment is down $0.8 billion or 0.2% by 1987, while productive investment falls $0.4 billion or 0.1%. Reduced aggregate demand also reduces prices. By 1987, the level of the implicit price deflator is down 1.9%, and its average annual rate of change falls to 7.6%. This means that about one-fourth of the inflationary effect of pollution control costs on prices can be attributed to the money supply assumptions in the base case.

SUMMARY

A comparison of the alternative simulations is shown in Table 10.

Table 1
Estimated Incremental Operating and Maintenance Costs For Pollution Control, 1970-1987
(Millions of 1979 dollars)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
TOTAL	3023	4395	6236	8622	9531	9965	10544	11375	12299	13579	14587	15936	17300	18329	20140	21625	23093	24830
All Indus.	959	1349	1864	2612	3386	4134	4944	5729	6489	7440	8409	9492	10812	12204	13768	15440	17114	18789
Mfg. Indus.	486	762	986	1403	1836	2302	2841	3311	3753	4270	4788	5385	6144	6931	7831	8805	9791	10770
Primary Metals	169	210	265	349	438	539	674	789	898	996	1101	1232	1379	1524	1684	1836	1980	2119
Elec. Machinery	3	6	10	18	25	32	37	42	47	71	91	114	146	181	224	275	334	398
Non-elec. Mach.	4	6	9	15	22	29	34	40	45	62	75	90	107	122	140	165	186	207
Transp. Equip.	4	16	31	51	72	91	102	113	123	162	206	265	343	436	545	670	794	917
Stone, Clay, Glass	1	12	26	48	71	101	123	134	144	163	181	202	231	270	315	368	424	484
Oth. Durables	7	18	35	62	92	130	160	181	200	237	270	310	357	413	476	547	615	682
Food incl. Beverage	9	24	43	68	94	117	135	156	177	196	212	229	249	272	300	335	371	412
Textiles	6	8	10	14	17	20	24	29	34	37	40	43	49	57	65	76	88	98
Paper	6	35	72	122	173	242	322	372	420	448	484	520	556	604	651	698	745	791
Chemical	177	213	257	315	374	450	552	671	785	852	905	963	1116	1270	1478	1726	1990	2249
Petroleum	96	148	220	328	441	527	648	747	837	993	1159	1343	1526	1681	1833	1969	2102	2232
Rubber	2	3	3	5	6	9	11	13	15	21	27	33	40	47	56	66	78	89
Oth. Nondurables	2	3	5	8	11	15	19	24	28	32	37	41	45	54	64	74	84	92
Nonmanufacturing	473	674	878	1209	1550	1832	2103	2418	2736	3170	3639	4107	4668	5273	5937	6635	7323	8019
Mining	54	60	69	81	92	95	102	111	116	132	148	165	184	203	224	245	268	290
Public Utilities	400	540	727	997	1276	1537	1780	2066	2359	2755	3189	3615	4119	4667	5271	5910	6537	7172
Commercial	19	47	82	131	182	200	221	241	261	283	302	327	365	403	442	480	518	557
State and Local Govt.	0	27	61	100	175	284	398	537	692	832	983	1134	1268	1380	1486	1583	1672	1752
Mobile Source Controls	2064	3019	4311	5910	5970	5547	5202	5109	5118	5307	5195	5310	5220	4745	4886	4602	4307	4289

Table 2
Estimated Incremental Investment For Pollution Control, 1970-1987
(Millions of 1979 dollars)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
TOTAL	3375	5086	6558	7524	8418	10308	11745	11631	13036	13536	15641	19142	18787	20131	20366	20409	20369	20029
All Indus.	2872	3807	5480	5665	5422	6054	5779	5574	6760	7019	7573	9404	9898	11087	11811	11905	11908	11627
Mfg. Indus.	1694	2256	3272	3385	3613	4290	3733	3521	3951	3977	4541	5747	5960	6785	7332	7440	7402	7169
Primary Metals	314	422	650	686	772	1042	880	840	752	811	1010	1131	1110	1235	1168	1108	1066	1010
Elec. Machinery	16	26	41	42	40	27	29	26	130	114	126	177	194	240	285	328	354	309
Non-elec. Mach.	12	22	41	43	46	35	40	36	111	88	97	114	100	125	161	145	140	142
Transp. Equip.	69	88	120	124	110	63	65	62	224	261	350	455	546	644	734	728	728	760
Stone, Clay, Glass	89	118	183	195	249	183	88	82	164	145	176	245	327	369	442	470	499	459
Oth. Durables	55	84	139	146	190	152	106	96	181	166	199	235	281	317	355	338	336	343
Food incl. Beverage	137	174	230	234	206	162	196	188	172	148	150	188	209	251	371	323	375	386
Textiles	19	25	32	32	30	42	50	48	29	31	36	51	81	84	112	113	108	105
Paper	243	310	416	424	569	668	419	396	239	297	300	300	397	394	393	390	388	305
Chemicals	293	372	485	491	626	857	990	945	565	440	476	1281	1284	1732	2066	2196	2162	2274
Petroleum	436	598	903	935	720	1010	820	757	1294	1385	1536	1521	1293	1267	1134	1110	1081	921
Rubber	2	6	13	14	32	18	21	20	58	62	58	68	78	88	96	76	56	55
Oth. Nondurables	11	13	19	20	26	30	28	27	32	29	27	31	60	64	65	65	59	50
Nonmanufacturing	1178	1551	2207	2280	1809	1764	2046	2053	2809	3042	3032	3157	3638	4099	4529	4465	4506	4458
Mining	69	88	115	115	28	74	83	57	152	167	171	186	194	203	215	224	220	216
Public Utilities	876	1167	1687	1743	1634	1516	1790	1833	2472	2715	2658	3151	3426	3776	3994	3921	3964	3920
Commercial	234	296	407	422	147	175	172	164	185	160	203	320	318	320	320	320	322	322
State and Local Govt.	-32	573	362	167	1610	1809	3079	2699	2844	2831	2838	2530	2024	1961	1340	1252	1160	1044
Mobile Source Controls	535	706	716	1692	1386	2445	2887	3360	3432	3686	5230	7208	6865	7083	7215	7252	7301	7358

Table 3
Estimated Impact of Incremental Pollution Control Costs, 1970-1987

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Gross National Product																		
WITHBASE	992.8	1077.6	1186.3	1327.2	1435.3	1549.9	1718.7	1920.2	2159.6	2417.9	2632.7	2924.7	3318.0	3732.5	4180.7	4737.2	5268.7	5847.0
WITHOUT	989.5	1070.8	1176.2	1312.7	1417.7	1527.2	1688.7	1883.3	2114.5	2359.0	2558.4	2832.3	3202.5	3587.2	4000.7	4508.0	4978.2	5484.5
DIFF	3.3	6.8	10.1	14.5	17.6	22.6	30.0	36.9	45.0	58.8	74.3	92.4	115.5	145.3	180.0	229.1	290.5	362.5
%DIFF	0.3	0.6	0.9	1.1	1.2	1.5	1.8	2.0	2.1	2.5	2.9	3.3	3.6	4.1	4.5	5.1	5.8	6.6
Real GNP (79$)																		
WITHBASE	1770.5	1830.6	1934.8	2047.2	2034.8	2011.9	2119.9	2237.3	2344.5	2417.9	2414.6	2428.6	2510.3	2582.5	2669.9	2780.0	2849.4	2927.3
WITHOUT	1766.1	1822.9	1925.6	2038.3	2028.5	2007.3	2115.2	2234.8	2343.9	2417.7	2415.9	2432.6	2517.3	2591.8	2682.6	2795.6	2867.2	2949.1
DIFF	4.4	7.7	9.2	8.9	6.3	4.7	4.7	2.5	0.6	0.2	-1.3	-4.0	-6.9	-9.3	-12.7	-15.6	-17.9	-21.8
%DIFF	0.2	0.4	0.5	0.4	0.3	0.2	0.2	0.1	0.0	0.0	-0.1	-0.2	-0.3	-0.4	-0.5	-0.6	-0.6	-0.7
Annual Rate of Change																		
WITHBASE	-0.2	3.4	5.7	5.8	-0.6	-1.1	5.4	5.5	4.8	3.1	-0.1	0.6	3.4	2.9	3.4	4.1	2.5	2.7
WITHOUT	-0.4	3.2	5.6	5.9	-0.5	-1.0	5.4	5.7	4.9	3.1	-0.1	0.7	3.5	3.0	3.5	4.2	2.6	2.9
DIFF	0.2	0.2	0.1	0.0	-0.1	-0.1	0.0	-0.1	-0.1	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
%DIFF	-57.9	5.6	1.0	-0.7	25.8	7.5	-0.2	-2.0	-1.9	-0.5	81.0	-16.1	-3.3	-2.9	-3.4	-2.1	-2.5	-4.3
Prices ------																		
Implicit Price Deflator (79=1.000)																		
WITHBASE	0.561	0.589	0.613	0.648	0.705	0.770	0.811	0.858	0.921	1.000	1.090	1.204	1.322	1.445	1.566	1.704	1.849	1.997
WITHOUT	0.560	0.587	0.611	0.644	0.699	0.761	0.798	0.843	0.902	0.976	1.059	1.164	1.272	1.384	1.491	1.613	1.736	1.860
DIFF	0.000	0.001	0.002	0.004	0.006	0.009	0.012	0.016	0.019	0.024	0.031	0.040	0.050	0.061	0.075	0.091	0.113	0.138
%DIFF	0.081	0.216	0.382	0.665	0.923	1.247	1.553	1.843	2.106	2.487	2.959	3.434	3.893	4.426	4.997	5.674	6.499	7.405
Wholesale Price Index (79=1.000)																		
WITHBASE	0.467	0.483	0.504	0.571	0.678	0.741	0.776	0.823	0.888	1.000	1.141	1.290	1.451	1.624	1.775	1.949	2.147	2.347
WITHOUT	0.467	0.481	0.501	0.565	0.669	0.729	0.760	0.804	0.865	0.971	1.102	1.240	1.387	1.543	1.677	1.827	1.992	2.152
DIFF	0.000	0.001	0.003	0.005	0.009	0.013	0.015	0.019	0.023	0.029	0.039	0.050	0.063	0.080	0.098	0.122	0.156	0.195
%DIFF	0.106	0.303	0.549	0.951	1.381	1.718	2.028	2.342	2.619	3.010	3.548	4.060	4.571	5.202	5.854	6.690	7.810	9.044
Consumer Price Index (79=1.000)																		
WITHBASE	0.534	0.556	0.575	0.611	0.678	0.740	0.783	0.834	0.898	1.000	1.134	1.265	1.394	1.527	1.654	1.796	1.949	2.107
WITHOUT	0.533	0.555	0.573	0.607	0.672	0.731	0.771	0.819	0.880	0.976	1.103	1.225	1.346	1.468	1.583	1.709	1.842	1.977
DIFF	0.000	0.001	0.002	0.004	0.006	0.009	0.012	0.015	0.019	0.024	0.031	0.040	0.048	0.058	0.071	0.087	0.107	0.130
%DIFF	0.073	0.196	0.357	0.634	0.939	1.264	1.559	1.84'	2.112	2.421	2.818	3.261	3.540	3.980	4.494	5.115	5.825	6.500
Annual Rate of Change																		
WITHBASE	5.9	4.2	3.3	6.3	11.1	9.1	5.7	6.5	7.8	11.3	13.4	11.5	10.2	9.5	8.4	8.6	8.5	8.1
WITHOUT	5.8	4.1	3.2	6.0	10.7	8.8	5.4	6.2	7.5	11.0	13.0	11.0	9.9	9.0	7.8	7.9	7.8	7.4
DIFF	0.1	0.1	0.2	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.4	0.5	0.3	0.5	0.5	0.6	0.7	0.8
%DIFF	1.3	3.1	5.3	4.9	3.1	4.0	5.7	4.8	3.8	3.1	3.4	4.3	3.0	5.1	6.8	8.1	9.3	10.4
Investment ----------																		
Real Business Fixed Investment (79$)																		
WITHBASE	195.5	192.6	207.9	237.2	233.1	204.7	215.2	241.1	263.5	280.4	270.5	262.9	276.8	291.4	305.8	323.9	319.5	349.9
WITHOUT	193.0	188.5	202.4	231.2	228.5	200.9	212.0	238.6	261.0	278.2	268.4	260.1	274.6	289.0	303.4	322.0	318.0	349.0
DIFF	2.5	4.1	5.5	6.0	4.6	3.9	3.2	2.5	2.5	2.2	2.1	2.9	2.3	2.3	2.4	1.9	1.6	0.9
%DIFF	1.3	2.2	2.7	2.6	2.0	1.9	1.5	1.0	1.0	0.8	0.8	1.1	0.8	0.8	0.6	0.6	0.5	0.3

Table 3 (Continued)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Producers' Durable Equipment																		
WITHBASE	111.9	111.0	123.1	145.3	147.5	129.7	137.6	160.0	174.3	183.8	175.2	171.0	179.9	190.0	199.4	211.3	222.1	229.9
WITHOUT	109.7	107.8	118.6	140.5	143.5	125.9	134.4	157.1	171.1	181.0	172.0	166.8	176.2	186.1	195.5	207.9	219.1	227.5
DIFF	2.2	3.3	4.5	4.8	4.0	3.9	3.2	2.9	3.2	2.9	3.3	4.2	3.7	3.9	3.9	3.4	3.1	2.5
%DIFF	2.0	3.0	3.8	3.4	2.8	3.1	2.4	1.8	1.9	1.6	1.9	2.5	2.1	2.1	2.0	1.7	1.4	1.1
Nonresidential Construction																		
WITHBASE	87.4	85.2	88.0	94.3	86.9	76.1	78.4	80.6	88.8	96.5	95.8	92.3	97.3	101.5	106.6	112.8	117.5	119.8
WITHOUT	87.3	84.5	87.2	93.3	86.5	76.4	78.8	81.3	89.9	97.6	97.4	94.2	99.3	103.7	108.7	114.8	119.5	121.8
DIFF	0.1	0.7	0.7	1.0	0.4	-0.3	-0.3	-0.7	-1.1	-1.1	-1.6	-2.0	-2.0	-2.1	-2.1	-2.1	-2.0	-2.0
%DIFF	0.1	0.8	0.8	1.0	0.4	-0.4	-0.4	-0.9	-1.2	-1.1	-1.7	-2.1	-2.0	-2.1	-2.0	-1.8	-1.7	-1.7
Housing Starts (mil. units)																		
WITHBASE	1.44	2.04	2.36	2.05	1.33	1.16	1.53	1.97	2.01	1.72	1.32	1.40	1.84	1.77	1.82	2.06	2.06	2.09
WITHOUT	1.44	2.05	2.39	2.08	1.37	1.19	1.59	2.05	2.10	1.80	1.38	1.47	1.93	1.88	1.96	2.19	2.17	2.21
DIFF	0.00	-0.01	-0.02	-0.03	-0.04	-0.03	-0.06	-0.08	-0.09	-0.08	-0.05	-0.07	-0.08	-0.11	-0.14	-0.13	-0.11	-0.11
%DIFF	-0.25	-0.66	-0.94	-1.67	-2.68	-2.87	-3.48	-4.14	-4.21	-4.34	-3.78	-4.66	-4.35	-5.62	-6.91	-5.97	-5.11	-5.19
Trade -----																		
Real Imports (79$)																		
WITHBASE	163.6	170.4	188.6	201.0	198.3	175.3	207.8	224.2	253.2	268.4	266.5	266.4	283.9	297.9	307.0	323.4	336.0	344.7
WITHOUT	162.7	168.7	186.4	198.7	196.7	174.5	208.1	224.9	254.0	269.3	266.9	267.0	285.9	300.6	310.8	327.5	339.8	348.4
DIFF	1.0	1.7	2.2	2.4	1.6	0.7	-0.3	-0.7	-0.8	-1.0	-0.4	-0.6	-2.0	-2.7	-3.8	-4.1	-3.8	-3.7
%DIFF	0.6	1.0	1.2	1.2	0.8	0.4	-0.1	-0.3	-0.3	-0.4	-0.2	-0.2	-0.7	-0.9	-1.2	-1.3	-1.1	-1.1
Real Exports (79$)																		
WITHBASE	135.3	136.2	148.7	186.7	208.2	198.7	211.3	217.2	244.7	281.8	309.9	308.8	323.1	338.1	348.5	356.3	360.1	371.7
WITHOUT	135.4	136.4	149.0	187.1	208.6	198.7	210.7	216.2	243.6	280.6	308.9	307.8	321.9	337.0	347.7	356.3	361.3	373.8
DIFF	0.0	-0.2	-0.3	-0.4	-0.4	0.1	0.6	1.0	1.1	1.3	1.0	1.0	1.2	1.2	0.8	0.0	-1.2	-2.0
%DIFF	0.0	-0.1	-0.2	-0.2	-0.2	0.0	0.3	0.5	0.5	0.4	0.3	0.3	0.4	0.3	0.2	0.0	-0.3	-0.5
Real Consumption (79$) ---- ----------- -----																		
Motor Vehicles & Parts																		
WITHBASE	59.2	70.6	81.3	87.6	72.9	73.4	88.7	98.4	101.9	95.6	83.1	86.9	96.5	95.8	103.2	109.6	111.4	114.2
WITHOUT	59.1	70.3	81.1	87.8	73.5	74.8	90.5	100.6	104.7	98.7	86.8	91.9	102.0	101.6	109.5	116.2	118.0	121.2
DIFF	0.0	0.2	0.2	-0.2	-0.7	-1.4	-1.8	-2.2	-2.8	-3.1	-3.6	-4.9	-5.5	-5.9	-6.3	-6.6	-6.6	-7.0
%DIFF	0.1	0.4	0.2	-0.2	-0.9	-1.9	-2.0	-2.2	-2.7	-3.1	-4.2	-5.4	-5.4	-5.8	-5.8	-5.6	-5.6	-5.8
Other Durables																		
WITHBASE	70.2	72.6	80.9	89.4	90.1	89.8	95.4	103.3	111.3	117.0	112.8	114.6	119.0	123.6	131.1	139.0	143.3	148.3
WITHOUT	70.1	72.3	80.7	89.4	90.3	90.4	95.8	104.0	112.1	118.0	113.6	115.7	120.4	125.4	133.2	141.2	145.5	150.6
DIFF	0.1	0.3	0.2	0.0	-0.2	-0.6	-0.5	-0.7	-0.8	-0.9	-0.9	-1.1	-1.4	-1.7	-2.1	-2.2	-2.2	-2.3
%DIFF	0.2	0.4	0.3	0.0	-0.2	-0.6	-0.5	-0.7	-0.7	-0.8	-0.8	-0.9	-1.2	-1.4	-1.6	-1.6	-1.5	-1.5
Nondurables																		
WITHBASE	482.9	491.2	511.6	524.1	516.1	524.4	548.5	568.2	588.3	601.2	608.2	605.4	610.6	620.4	633.0	648.1	660.1	672.4
WITHOUT	481.6	489.1	508.6	520.4	512.9	521.7	546.1	566.0	586.5	601.7	607.2	604.8	610.6	621.2	634.7	650.5	663.1	676.5
DIFF	1.3	2.2	3.0	3.7	3.1	2.6	2.4	2.2	1.8	1.5	1.0	0.6	0.0	-0.8	-1.7	-2.4	-3.1	-4.1
%DIFF	0.3	0.4	0.6	0.7	0.6	0.5	0.4	0.4	0.3	0.2	0.2	0.1	0.0	-0.1	-0.3	-0.4	-0.5	-0.6
Services																		
WITHBASE	485.7	503.0	527.9	550.5	564.7	583.0	607.9	615.4	670.0	697.2	715.4	735.1	754.5	777.3	806.2	837.9	867.1	896.5
WITHOUT	484.7	501.4	526.0	548.3	561.0	581.7	606.7	614.5	669.7	697.3	716.3	736.5	756.6	780.2	809.6	842.1	871.7	901.9
DIFF	1.0	1.6	2.0	2.1	1.7	1.4	1.2	0.9	0.3	-0.1	-0.9	-1.4	-2.2	-2.9	-3.4	-4.1	-4.7	-5.3
%DIFF	0.2	0.3	0.4	0.4	0.3	0.2	0.2	0.1	0.0	0.0	-0.1	-0.2	-0.3	-0.4	-0.4	-0.5	-0.5	-0.6

Table 3 (Continued)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Incomes																		

Disposable Income																		
WITHBASE	695.3	751.8	810.4	914.9	999.0	1096.7	1195.1	1312.8	1464.8	1644.2	1824.9	2038.4	2301.8	2580.6	2888.4	3239.9	3599.4	3987.1
WITHOUT	694.0	748.6	805.5	907.2	988.3	1081.9	1175.2	1287.9	1433.6	1603.7	1772.8	1972.5	2220.6	2476.3	2760.0	3079.1	3398.2	3739.2
DIFF	1.3	3.1	4.9	7.7	10.7	14.9	19.9	24.9	31.1	40.5	52.1	65.9	81.3	104.3	128.4	160.7	201.2	247.9
%DIFF	0.2	0.4	0.6	0.8	1.1	1.4	1.7	1.9	2.2	2.5	2.9	3.3	3.7	4.2	4.7	5.2	5.9	6.6
Real Disposable Income (79$)																		
WITHBASE	1221.7	1266.8	1317.3	1406.9	1395.5	1423.4	1474.6	1527.6	1595.5	1641.9	1654.9	1672.2	1723.4	1766.6	1826.4	1894.4	1946.4	1998.8
WITHOUT	1220.3	1264.0	1314.0	1404.2	1394.6	1423.5	1474.8	1529.1	1597.7	1647.0	1659.7	1679.4	1731.3	1775.3	1837.3	1906.2	1958.8	2013.7
DIFF	1.4	2.8	3.3	2.6	0.9	-0.1	-0.2	-1.4	-2.1	-3.1	-4.8	-7.2	-7.9	-8.6	-10.9	-11.8	-12.4	-14.9
%DIFF	0.1	0.2	0.2	0.2	0.1	0.0	0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.5	-0.6	-0.6	-0.6	-0.7
Before-tax Corporate Profits																		
WITHBASE	75.5	86.5	100.8	126.0	136.9	132.1	166.2	193.1	224.3	256.2	245.6	230.7	265.4	295.3	313.2	391.4	403.6	433.2
WITHOUT	74.5	84.8	98.8	123.4	135.2	130.6	164.4	191.1	222.5	252.2	240.4	226.1	259.4	286.6	301.5	372.0	377.6	400.4
DIFF	1.0	1.7	2.0	2.5	1.7	1.5	1.7	2.0	1.8	4.0	5.3	4.7	6.0	8.7	11.7	19.4	26.0	32.8
%DIFF	1.3	2.0	2.0	2.1	1.3	1.1	1.1	1.0	0.8	1.6	2.2	2.1	2.3	3.0	3.9	5.2	6.9	8.2
Aftertax Corporate Profits																		
WITHBASE	41.3	49.0	59.1	76.8	85.3	81.5	102.4	120.3	140.9	168.3	164.3	152.1	173.3	193.2	206.0	254.4	264.8	285.1
WITHOUT	40.7	48.0	57.8	75.1	84.0	80.3	101.0	118.7	139.3	165.2	160.3	148.3	168.6	186.6	197.3	240.9	247.0	262.9
DIFF	0.5	1.0	1.2	1.7	1.2	1.2	1.4	1.6	1.6	3.1	4.0	3.8	4.7	6.6	8.7	13.5	17.8	22.2
%DIFF	1.3	2.1	2.2	2.2	1.4	1.5	1.4	1.3	1.2	1.9	2.5	2.6	2.8	3.5	4.4	5.6	7.2	8.5
Real Aftertax Profits (79$)																		
WITHBASE	76.5	86.7	100.6	125.2	125.5	105.8	127.1	140.8	153.0	168.3	150.7	128.5	133.5	136.4	134.3	152.7	146.9	146.7
WITHOUT	75.6	85.1	99.0	123.5	125.1	105.7	127.6	141.8	154.8	169.7	151.8	129.9	135.3	138.1	135.7	153.7	147.0	146.6
DIFF	1.0	1.5	1.7	1.7	0.4	0.1	-0.5	-1.0	-1.8	-1.4	-1.0	-1.4	-1.9	-1.7	-1.4	-1.0	-0.1	0.1
%DIFF	1.3	1.8	1.7	1.4	0.3	0.1	-0.4	-0.7	-1.1	-0.8	-0.7	-1.1	-1.4	-1.2	-1.0	-0.7	-0.1	0.1
Other Indicators																		
----- ----------																		
State & Local Gov't Bond Rate (%)																		
WITHBASE	6.12	5.22	5.04	5.00	5.90	6.43	5.66	5.20	5.52	5.93	7.86	8.76	9.00	8.42	8.08	8.42	8.36	8.08
WITHOUT	6.10	5.16	4.95	4.86	5.71	6.21	5.44	4.97	5.27	5.64	7.51	8.39	8.60	7.99	7.63	7.95	7.86	7.54
DIFF	0.02	0.05	0.09	0.14	0.19	0.21	0.23	0.24	0.26	0.29	0.34	0.37	0.40	0.43	0.45	0.47	0.51	0.54
%DIFF	0.32	1.06	1.81	2.79	3.39	3.46	4.17	4.79	4.92	5.22	4.57	4.40	4.70	5.39	5.83	5.90	6.43	7.22
Unemployment Rate (%)																		
WITHBASE	5.0	6.0	5.6	4.8	5.6	8.5	7.7	7.0	6.0	5.8	7.2	7.8	7.1	7.0	7.0	6.5	6.3	6.2
WITHOUT	5.1	6.1	5.8	5.1	5.8	8.7	7.9	7.3	6.2	6.0	7.5	8.1	7.4	7.4	7.4	6.9	6.7	6.7
DIFF	-0.1	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.4	-0.4	-0.4
%DIFF	-1.9	-3.1	-4.0	-4.6	-3.6	-2.2	-2.7	-3.2	-1.6	-4.2	-3.8	-3.7	-4.1	-4.4	-4.6	-5.3	-5.9	-6.2
Industrial Production Index (79=1.000)																		
WITHBASE	0.707	0.718	0.785	0.851	0.848	0.772	0.854	0.906	0.959	1.000	0.963	0.977	1.059	1.105	1.153	1.229	1.258	1.292
WITHOUT	0.705	0.715	0.783	0.849	0.849	0.775	0.857	0.910	0.966	1.006	0.970	0.987	1.070	1.117	1.169	1.246	1.274	1.310
DIFF	0.001	0.003	0.003	0.002	-0.001	-0.003	-0.003	-0.005	0.007	-0.006	-0.007	-0.010	-0.012	-0.013	-0.015	-0.016	-0.016	-0.018
%DIFF	0.200	0.438	0.340	0.216	-0.092	-0.391	-0.393	-0.495	0.707	-0.619	-0.714	-0.991	-1.083	-1.150	-1.308	-1.298	-1.260	-1.305

Table 4
Incremental Pollution Control Costs Used In Each Simulation
(Millions of 1979 dollars)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
BASE CASE:																		
Incremental Investment	3375	5086	6558	7524	8418	10308	11745	11633	13036	13536	15641	19142	18787	20131	20366	20409	20369	20029
Incremental O&M	3023	4395	6236	8622	9531	9965	10544	11375	12299	13579	14587	15936	17300	18329	20140	21625	23093	24830
HIGH COST:																		
Incremental Investment	3375	5086	6558	7524	8418	10308	11745	11633	13036	14164	16531	20003	19616	20476	21028	21449	21587	21188
Incremental O&M	3023	4395	6236	8622	9531	9965	10544	11375	12299	13579	14587	15936	17300	18829	20640	22625	24593	26330
LOW COST:																		
Incremental Investment	3375	5086	6558	7524	8418	10308	11745	11633	13036	13536	15641	17228	15030	14092	12220	10205	8148	6009
Incremental O&M	3023	4395	6236	8622	9531	9965	10544	11375	12299	13579	14587	14342	13840	12830	12084	10812	9237	7449
CONSTANT MONEY SUPPLY:																		
Incremental Investment									Same as Base Case									
Incremental O&M									Same as Base Case									
WITHOUT:																		
Incremental Investment										-0-								
Incremental O&M										-0-								

Table 5
Assumptions in the High and Low Pollution Control Cost Alternatives
(Millions of 1979 dollars)

HIGH COST CASE

	STATE AND LOCAL		MOBILE SOURCE CONTROLS					
	INCREMENTAL INVESTMENT	DIFFERENCE FROM WITH CASE	INCREMENTAL INVESTMENT	DIFFERENCE FROM WITH CASE	OPERATING AND MAINTENANCE COSTS	DIFFERENCE FROM WITH CASE	TOTAL DIFFERENCE FROM WITH CASE	PERCENT OF WITH CASE
1979	3459	628	3686	---	5307	---	628	2.3
1980	3728	890	5730	---	5195	---	890	2.9
1981	3391	861	7208	---	5310	---	861	2.5
1982	2853	829	6865	---	5220	---	829	2.3
1983	2206	245	7183	100	5245	500	845	2.2
1984	1802	462	7415	200	5306	500	1162	2.9
1985	1992	740	7552	300	5602	1000	2040	4.9
1986	2078	918	7601	300	5807	1500	2718	6.3
1987	1903	859	7658	300	5789	1500	2659	5.9

LOW COST CASE

	TOTAL INCREMENTAL COSTS	PERCENT OF WITH CASE
1981	31570	90
1982	28870	80
1983	26922	70
1984	24304	60
1985	21017	50
1986	17385	40
1987	13458	30

Table 6
Assumptions in the Constant Money Supply Case

	DESIRED REDUCTION IN MONEY SUPPLY (BILLIONS)	REQUIRED DECREASE IN NONBORROWED RESERVES (IN BILLIONS)
1970	0.2	0.00
1971	0.4	0.06
1972	0.6	0.12
1973	0.8	0.09
1974	0.9	0.23
1975	1.2	0.13
1976	1.4	0.17
1977	1.7	0.20
1978	2.0	0.26
1979	2.6	0.42
1980	3.1	0.30
1981	3.8	0.57
1982	4.6	0.51
1983	5.7	0.56
1984	7.2	0.62
1985	9.1	0.67
1986	11.5	0.78
1987	14.3	0.78

Table 7
Estimated Impact of Incremental Pollution Control Costs, 1970-1987
Higher Pollution Control Costs

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Gross National Product																		
WITHBASE	992.8	1077.6	1186.3	1327.2	1435.3	1549.9	1718.7	1920.2	2159.6	2417.9	2632.7	2924.7	3318.0	3732.5	4180.7	4737.2	5268.7	5847.0
WITHHIGH	992.8	1077.6	1186.3	1327.2	1435.3	1549.9	1718.7	1920.2	2159.6	2418.3	2633.7	2926.1	3319.7	3734.7	4184.3	4743.9	5279.8	5862.1
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.4	-1.0	-1.4	-1.7	-2.2	-3.6	-6.8	-11.2	-15.1
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.3
Real GNP (79$)																		
WITHBASE	1770.5	1830.6	1934.8	2047.2	2034.8	2011.9	2119.9	2237.3	2344.5	2417.9	2414.6	2428.6	2510.3	2582.5	2669.9	2780.0	2849.4	2927.3
WITHHIGH	1770.5	1830.6	1934.8	2047.2	2034.8	2011.9	2119.9	2237.3	2344.5	2418.3	2415.3	2429.5	2511.2	2583.3	2671.0	2782.1	2852.4	2930.5
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.4	-0.8	-0.9	-0.9	-0.8	-1.2	-2.1	-3.0	-3.2
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1
Annual Rate of Change																		
WITHBASE	-0.2	3.4	5.7	5.8	-0.6	-1.1	5.4	5.5	4.8	3.1	-0.1	0.6	3.4	2.9	3.4	4.1	2.5	2.7
WITHHIGH	-0.2	3.4	5.7	5.8	-0.6	-1.1	5.4	5.5	4.8	3.1	-0.1	0.6	3.4	2.9	3.4	4.2	2.5	2.7
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.5	13.7	-0.7	0.1	0.0	-0.4	-0.8	-1.3	-0.1
Prices																		

Implicit Price Deflator (79=1.000)																		
WITHBASE	0.561	0.589	0.613	0.648	0.705	0.770	0.811	0.858	0.921	1.000	1.090	1.204	1.322	1.445	1.566	1.704	1.849	1.997
WITHHIGH	0.561	0.589	0.613	0.648	0.705	0.770	0.811	0.858	0.921	1.000	1.090	1.204	1.322	1.446	1.567	1.705	1.851	2.000
DIFF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	-0.001	-0.002	-0.003
%DIFF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.003	-0.008	-0.012	-0.017	-0.025	-0.041	-0.068	-0.105	-0.150
Wholesale Price Index (79=1.000)																		
WITHBASE	0.467	0.483	04	0.571	0.678	0.741	0.776	0.823	0.888	1.000	1.141	1.290	1.451	1.624	1.775	1.949	2.147	2.347
WITHHIGH	0.467	0.483	0.504	0.571	0.678	0.741	0.776	0.823	0.888	1.000	1.141	1.290	1.451	1.624	1.775	1.951	2.150	2.352
DIFF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	-0.002	-0.003	-0.005
%DIFF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.003	-0.007	-0.012	-0.018	-0.027	-0.046	-0.080	-0.135	-0.198
Consumer Price Index (79=1.000)																		
WITHBASE	0.534	0.556	0.575	0.611	0.678	0.740	0.783	0.834	0.898	1.000	1.134	1.265	1.394	1.527	1.654	1.796	1.949	2.107
WITHHIGH	0.534	0.556	0.575	0.611	0.678	0.740	0.783	0.834	0.898	1.000	1.135	1.265	1.394	1.527	1.655	1.797	1.951	2.110
DIFF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	-0.001	-0.002	-0.003
%DIFF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.002	-0.008	-0.014	-0.020	-0.029	-0.042	-0.063	-0.094	-0.136
Annual Rate of Change																		
WITHBASE	5.9	4.2	3.3	6.3	11.1	9.1	5.7	6.5	7.8	11.3	13.4	11.5	10.2	9.5	8.4	8.6	8.5	8.1
WITHHIGH	5.9	4.2	3.3	6.3	11.1	9.1	5.7	6.5	7.8	11.3	13.5	11.5	10.2	9.5	8.4	8.6	8.6	8.2
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.2	-0.3	-0.4	-0.6
Investment																		

Real Business Fixed Investment (79$)																		
WITHBASE	195.5	192.6	207.9	237.2	233.1	204.7	215.2	241.1	263.5	280.4	270.5	262.9	276.8	291.4	305.8	323.9	339.5	349.9
WITHHIGH	195.5	192.6	207.9	237.2	233.1	204.7	215.2	241.1	263.5	280.4	270.5	263.0	276.9	291.5	306.0	324.3	340.1	350.5
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.4	-0.5	-0.6
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.2	-0.2

Table 7 (Continued)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Producers' Durable Equipment																		
WITHBASE	111.9	111.0	123.1	145.3	147.5	129.7	137.6	160.0	174.3	183.8	175.2	171.0	179.9	190.0	199.4	211.3	222.1	229.9
WITHHIGH	111.9	111.0	123.1	145.3	147.5	129.7	137.6	160.0	174.3	183.9	175.3	171.1	180.0	190.2	199.6	211.6	222.6	230.4
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.2	-0.2	-0.2
Nonresidential Construction																		
WITHBASE	87.4	85.2	88.0	94.3	86.9	76.1	78.4	80.6	88.8	96.5	95.8	92.3	97.3	101.5	106.6	112.8	117.5	119.8
WITHHIGH	87.4	85.2	88.0	94.3	86.9	76.1	78.4	80.6	88.8	96.5	95.8	92.3	97.3	101.5	106.6	112.8	117.6	119.9
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1
Housing Starts (mil. units)																		
WITHBASE	1.44	2.04	2.36	2.05	1.33	1.16	1.53	1.97	2.01	1.72	1.32	1.40	1.84	1.77	1.82	2.06	2.06	2.09
WITHHIGH	1.44	2.04	2.36	2.05	1.33	1.16	1.53	1.97	2.01	1.72	1.32	1.40	1.84	1.77	1.82	2.06	2.06	2.09
DIFF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%DIFF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.09	0.14	0.14	0.13	0.09	0.13	0.19	0.24
Trade -----																		
Real Imports (79$)																		
WITHBASE	163.6	170.4	188.6	201.0	198.3	175.3	207.8	224.2	253.2	268.4	266.5	266.4	283.9	297.9	307.0	323.4	336.0	344.7
WITHHIGH	163.6	170.4	188.6	201.0	198.3	175.3	207.8	224.2	253.2	268.4	266.6	266.5	284.0	298.1	307.2	323.6	336.3	344.9
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.2	-0.3	-0.2
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1
Real Exports (79$)																		
WITHBASE	135.3	136.2	148.7	186.7	208.2	198.7	211.3	217.2	244.7	281.8	309.9	308.8	323.1	338.1	348.5	356.3	360.1	371.7
WITHHIGH	135.3	136.2	148.7	186.7	208.2	198.7	211.3	217.2	244.7	281.8	309.9	308.8	323.2	338.2	348.6	356.4	360.2	372.0
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.2	-0.2
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
Real Consumption (79$) ---- ----------- -----																		
Motor Vehicles & Parts																		
WITHBASE	59.2	70.6	81.3	87.6	72.9	73.4	88.7	98.4	101.9	95.6	83.1	86.9	96.5	95.8	103.2	109.6	111.4	114.2
WITHHIGH	59.2	70.6	81.3	87.6	72.9	73.4	88.7	98.4	101.9	95.6	83.2	87.0	96.5	95.8	103.2	109.6	111.4	114.2
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Durables																		
WITHBASE	70.2	72.6	80.9	89.4	90.1	89.8	95.4	103.3	111.3	117.0	112.8	114.6	119.0	123.6	131.1	139.0	143.3	148.3
WITHHIGH	70.2	72.6	80.9	89.4	90.1	89.8	95.4	103.3	111.3	117.1	112.8	114.6	119.1	123.7	131.1	139.0	143.4	148.4
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1
Nondurables																		
WITHBASE	482.8	491.2	511.6	524.1	516.1	524.4	548.5	568.2	588.3	603.2	608.2	605.4	610.6	620.4	633.0	648.1	660.1	672.4
WITHHIGH	482.8	491.2	511.6	524.1	516.1	524.4	548.5	568.2	588.3	603.2	608.3	605.5	610.7	620.7	633.3	648.7	661.0	673.3
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.3	-0.3	-0.6	-0.9	-0.9
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1
Services																		
WITHBASE	485.7	503.0	527.9	550.5	564.7	583.0	607.9	635.4	670.0	697.2	715.4	735.1	754.5	777.3	806.2	837.[illegible]	867.1	896.5
WITHHIGH	485.7	503.0	527.9	550.5	564.7	583.0	607.9	635.4	670.0	697.2	715.5	735.1	754.6	777.6	806.5	838.5	867.9	897.4
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.3	-0.3	-0.6	-0.9	-0.9
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1

Table 7 (Continued)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Incomes																		
Disposable Income																		
WITHBASE	695.3	751.8	810.4	914.9	999.0	1096.7	1195.1	1312.8	1464.8	1644.2	1824.9	2038.4	2303.8	2580.6	2888.4	3239.9	3599.4	3987.1
WITHHIGH	695.3	751.8	810.4	914.9	999.0	1096.7	1195.1	1312.8	1464.8	1644.4	1825.5	2039.2	2304.9	2581.9	2890.5	3243.9	3606.0	3996.4
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.6	-0.8	-1.0	-1.3	-2.2	-4.0	-6.7	-9.3
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.2	-0.2
Real Disposable Income (79$)																		
WITHBASE	1221.7	1266.8	1317.3	1406.9	1395.5	1423.4	1474.6	1527.6	1595.5	1643.9	1654.9	1672.2	1723.4	1766.6	1876.4	1894.4	1946.4	1998.8
WITHHIGH	1221.7	1266.8	1317.3	1406.9	1395.5	1423.4	1474.6	1527.6	1595.5	1644.1	1655.3	1672.6	1723.9	1766.7	1826.6	1894.8	1947.0	1999.5
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.4	-0.4	-0.5	-0.1	-0.2	-0.4	-0.6	-0.7
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Before-tax Corporate Profits																		
WITHBASE	75.5	86.5	100.8	126.0	136.9	132.1	166.2	193.1	224.3	256.2	245.6	230.7	265.4	295.3	313.2	391.4	403.6	433.2
WITHHIGH	75.5	86.5	100.8	126.0	136.9	132.1	166.2	193.1	224.3	256.3	245.8	230.9	265.5	295.7	313.9	392.7	405.6	435.4
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.2	-0.2	-0.1	-0.3	-0.6	-1.3	-2.0	-2.2
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	-0.1	-0.2	-0.3	-0.5	-0.5
Aftertax Corporate Profits																		
WITHBASE	41.3	49.0	59.1	76.8	85.3	81.5	102.4	120.3	140.9	168.3	164.3	152.1	173.3	193.2	206.0	254.4	264.8	285.1
WITHHIGH	41.3	49.0	59.1	76.8	85.3	81.5	102.4	120.3	140.9	168.4	164.4	152.2	173.4	193.4	206.4	255.2	266.0	286.5
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.4	-0.8	-1.2	-1.4
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	-0.1	-0.2	-0.3	-0.5	-0.5
Real Aftertax Profits (79$)																		
WITHBASE	76.5	86.7	100.6	125.2	125.5	105.8	127.1	140.8	153.0	168.3	150.7	128.5	133.5	136.4	134.3	152.7	146.9	146.7
WITHHIGH	76.5	86.7	100.6	125.2	125.5	105.8	127.1	140.8	153.0	168.4	150.8	128.5	133.5	136.5	134.5	153.0	147.4	147.1
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	-0.1	-0.2	-0.4	-0.5	-0.4
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	-0.1	-0.1	-0.2	-0.3	-0.3
Other Indicators																		
State & Local Gov't Bond Rate (%)																		
WITHBASE	6.12	5.22	5.04	5.00	5.90	6.43	5.66	5.20	5.52	5.93	7.86	8.76	9.00	8.42	8.08	8.42	8.36	8.08
WITHHIGH	6.12	5.22	5.04	5.00	5.90	6.43	5.66	5.20	5.52	5.93	7.86	8.77	9.01	8.43	8.09	8.43	8.38	8.11
DIFF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02	-0.03
%DIFF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	-0.06	-0.09	-0.10	-0.10	-0.12	-0.16	-0.25	-0.33
Unemployment Rate (%)																		
WITHBASE	5.0	6.0	5.6	4.8	5.6	8.5	7.7	7.0	6.0	5.8	7.2	7.8	7.1	7.0	7.0	6.5	6.3	6.2
WITHHIGH	5.0	6.0	5.6	4.8	5.6	8.5	7.7	7.0	6.0	5.8	7.2	7.8	7.1	7.0	7.0	6.5	6.3	6.2
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.4	0.5
Industrial Production Index (79=1.000)																		
WITHBASE	0.707	0.718	0.785	0.851	0.848	0.772	0.854	0.906	0.959	1.000	0.963	0.977	1.059	1.105	1.153	1.229	1.258	1.292
WITHHIGH	0.707	0.718	0.785	0.851	0.848	0.772	0.854	0.906	0.959	1.000	0.963	0.978	1.059	1.105	1.154	1.230	1.259	1.293
DIFF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	-0.001	-0.001
%DIFF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.011	-0.025	-0.024	-0.017	-0.024	-0.043	-0.073	-0.107	-0.104

Table 8
Estimated Impact of Incremental Control Costs, 1970-1987
Lower Pollution Control Costs

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Gross National Product																		
WITHBASE	992.8	1077.6	1186.3	1327.2	1435.3	1549.9	1718.7	1920.2	2159.6	2417.9	2632.7	2924.7	3318.0	3732.5	4180.7	4737.2	5268.7	5847.0
WITHLOW	992.8	1077.6	1186.3	1327.2	1435.3	1549.9	1718.7	1920.2	2159.6	2417.9	2632.7	2922.6	3312.0	3721.9	4164.9	4714.7	5235.4	5799.9
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	6.0	10.7	15.8	22.5	33.3	47.1
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.8
Real GNP (79$)																		
WITHBASE	1770.5	1830.6	1934.8	2047.2	2034.8	2011.9	2119.9	2237.1	2344.5	2417.9	2414.6	2428.6	2510.1	2582.5	2669.9	2780.0	2849.4	2927.3
WITHLOW	1770.5	1830.6	1934.8	2047.2	2034.8	2011.9	2119.9	2237.1	2344.5	2417.9	2414.6	2427.5	2508.1	2580.3	2668.4	2779.4	2849.3	2928.9
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	2.2	2.2	1.5	0.6	0.1	-1.6
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	-0.1
Annual Rate of Change																		
WITHBASE	-0.2	3.4	5.7	5.8	-0.6	-1.1	5.4	5.5	4.8	3.1	-0.1	0.6	3.4	2.9	3.4	4.1	2.5	2.7
WITHLOW	-0.2	3.4	5.7	5.8	-0.6	-1.1	5.4	5.5	4.8	3.1	-0.1	0.5	3.3	2.9	3.4	4.2	2.5	2.8
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.1	1.4	0.0	-0.9	-0.9	-0.7	-2.1
Prices ------																		
Implicit Price Deflator (79=1.000)"																		
WITHBASE	0.561	0.589	0.613	0.648	0.705	0.770	0.811	0.858	0.921	1.000	1.090	1.204	1.322	1.445	1.566	1.704	1.849	1.997
WITHLOW	0.561	0.589	0.613	0.648	0.705	0.770	0.811	0.858	0.921	1.000	1.090	1.204	1.321	1.442	1.561	1.696	1.837	1.980
DIFF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.005	0.008	0.012	0.017
%DIFF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.028	0.094	0.200	0.324	0.456	0.633	0.866
Wholesale Price Index (79=1.000)																		
WITHBASE	0.467	0.483	0.504	0.571	0.678	0.741	0.776	0.823	0.888	1.000	1.141	1.290	1.451	1.624	1.775	1.949	2.147	2.347
WITHLOW	0.467	0.483	0.504	0.571	0.678	0.741	0.776	0.823	0.888	1.000	1.141	1.289	1.449	1.618	1.765	1.936	2.128	2.318
DIFF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.006	0.009	0.014	0.020	0.029
%DIFF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.049	0.164	0.345	0.529	0.699	0.925	1.248
Consumer Price Index (79=1.000)																		
WITHBASE	0.534	0.556	0.575	0.611	0.678	0.740	0.783	0.834	0.898	1.000	1.134	1.265	1.394	1.527	1.654	1.796	1.949	2.107
WITHLOW	0.534	0.556	0.575	0.611	0.678	0.740	0.783	0.834	0.898	1.000	1.134	1.264	1.393	1.523	1.648	1.787	1.936	2.088
DIFF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.003	0.006	0.009	0.014	0.019
%DIFF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.037	0.108	0.225	0.358	0.510	0.690	0.926
Annual Rate of Change																		
WITHBASE	5.9	4.2	3.3	6.3	11.1	9.1	5.7	6.5	7.8	11.3	13.4	11.5	10.2	9.5	8.4	8.6	8.5	8.1
WITHLOW	5.9	4.2	3.3	6.3	11.1	9.1	5.7	6.5	7.8	11.3	13.4	11.4	10.2	9.4	8.2	8.4	8.3	7.9
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.8	1.4	1.7	2.0	2.4	3.1
Investment ----------																		
Real Business Fixed Investment (79$)																		
WITHBASE	195.5	192.6	207.9	237.2	233.1	204.7	215.2	241.1	263.5	280.4	270.5	262.9	276.8	291.4	305.8	323.9	339.5	349.9
WITHLOW	195.5	192.6	207.9	237.2	233.1	204.7	215.2	241.1	263.5	280.4	270.5	262.0	274.6	288.1	301.7	319.3	334.4	344.3
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	2.2	3.3	4.1	4.6	5.2	5.6
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.8	1.1	1.4	1.4	1.6	1.6

Table 8 (Continued)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Producers' Durable Equipment																		
WITHBASE	111.9	111.0	123.1	145.3	147.5	129.7	137.6	160.0	174.3	183.8	175.2	171.0	179.9	190.0	199.4	211.3	222.1	229.9
WITHLOW	111.9	111.0	123.1	145.3	147.5	129.7	137.6	160.0	174.3	183.8	175.2	170.2	178.0	187.1	195.6	206.9	217.0	224.2
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	2.0	3.0	3.9	4.5	5.2	5.7
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.1	1.6	2.0	2.2	2.4	2.5
Nonresidential Construction																		
WITHBASE	87.4	85.2	88.0	94.3	86.9	76.1	78.4	80.6	88.8	96.5	95.8	92.3	97.1	101.5	106.6	112.8	117.5	119.8
WITHLOW	87.4	85.2	88.0	94.3	86.9	76.1	78.4	80.6	88.8	96.5	95.8	92.2	97.1	101.4	106.6	112.9	117.9	120.4
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	-0.2	-0.4	-0.6
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	-0.2	-0.3	-0.5
Housing Starts (mil. units)																		
WITHBASE	1.44	2.04	2.36	2.05	1.33	1.16	1.53	1.97	2.01	1.72	1.32	1.40	1.84	1.77	1.82	2.06	2.06	2.09
WITHLOW	1.44	2.04	2.36	2.05	1.33	1.16	1.53	1.97	2.01	1.72	1.32	1.40	1.85	1.80	1.87	2.13	2.14	2.18
DIFF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.03	-0.05	-0.07	-0.08	-0.09
%DIFF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.22	-0.65	-1.49	-2.74	-3.35	-3.65	-4.14
Trade																		
Real Imports (79$)																		
WITHBASE	163.6	170.4	188.6	201.0	198.3	175.3	207.8	224.2	253.2	268.4	266.5	266.4	283.9	297.9	307.0	323.4	336.0	344.7
WITHLOW	163.6	170.4	188.6	201.0	198.3	175.3	207.8	224.2	253.2	268.4	266.5	265.9	282.9	296.8	306.2	323.1	335.9	344.6
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.0	1.2	0.8	0.3	0.1	0.0
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.4	0.3	0.1	0.0	0.0
Real Exports (79$)																		
WITHBASE	135.3	136.2	148.7	186.7	208.2	198.7	211.3	217.2	244.7	281.8	309.9	308.8	323.1	338.1	348.5	356.3	360.1	371.7
WITHLOW	135.3	136.2	148.7	186.7	208.2	198.7	211.3	217.2	244.7	281.8	309.9	308.9	323.1	338.0	348.2	355.5	358.8	370.1
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.8	1.3	1.7
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.4
Real Consumption (79$)																		
Motor Vehicles & Parts																		
WITHBASE	59.2	70.6	81.3	87.6	72.9	73.4	88.7	98.4	101.9	95.6	83.1	86.9	96.5	95.8	103.2	109.6	111.4	114.2
WITHLOW	59.2	70.6	81.3	87.6	72.9	73.4	88.7	98.4	101.9	95.6	83.1	87.1	96.8	96.5	104.4	111.3	113.4	116.7
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.3	-0.7	-1.2	-1.6	-2.0	-2.6
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.3	-0.7	-1.1	-1.5	-1.8	-2.2
Other Durables																		
WITHBASE	70.2	72.6	80.9	89.4	90.1	89.8	95.4	103.3	111.3	117.0	112.8	114.6	119.0	123.6	131.1	139.0	143.3	148.3
WITHLOW	70.2	72.6	80.9	89.4	90.1	89.8	95.4	103.3	111.3	117.0	112.8	114.6	119.1	123.9	131.6	139.9	144.7	150.3
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.6	-1.0	-1.4	-2.0
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.4	-0.7	-1.0	-1.3
Nondurables																		
WITHBASE	482.8	491.2	511.6	524.1	516.1	524.4	548.5	568.2	588.3	603.2	608.2	605.4	610.6	620.4	633.0	648.1	660.1	672.4
WITHLOW	482.8	491.2	511.6	524.1	516.1	524.4	548.5	568.2	588.3	603.2	608.2	605.1	610.0	619.6	632.2	647.3	659.3	671.7
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.6	0.7	0.8	0.8	0.8	0.7
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Services																		
WITHBASE	485.7	503.0	527.9	550.5	564.7	583.0	607.9	635.4	670.0	697.2	715.4	735.1	754.5	777.3	806.2	837.9	867.1	896.5
WITHLOW.	485.7	503.0	527.9	550.5	564.7	583.0	607.9	635.4	670.0	697.2	715.4	734.9	754.0	776.9	805.8	837.8	867.3	897.3
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.4	0.4	0.1	-0.3	-0.7
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	-0.1

Table 8 (Continued)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Incomes																		
Disposable Income																		
WITHBASE	695.3	751.8	810.4	914.9	999.0	1096.7	1195.1	1312.8	1464.8	1644.2	1824.9	2038.4	2303.8	2580.6	2888.4	3239.9	3599.4	3987.1
WITHLOW	695.3	751.8	810.4	914.9	999.0	1096.7	1195.1	1312.8	1464.8	1644.2	1824.9	2037.4	2300.4	2573.6	2876.9	3222.7	3574.2	3951.4
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	3.4	7.0	11.5	17.2	25.1	35.7
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.4	0.5	0.7	0.9
Real Disposable Income (79$)																		
WITHBASE	1221.7	1266.8	1317.3	1406.9	1395.5	1423.4	1474.6	1527.6	1595.5	1641.9	1654.9	1672.2	1773.4	1766.6	1826.4	1894.4	1946.4	1998.8
WITHLOW	1221.7	1266.8	1317.3	1406.9	1395.5	1423.4	1474.6	1527.6	1595.5	1641.9	1654.9	1672.3	1773.5	1767.1	1827.8	1896.8	1949.8	2003.5
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.5	-1.4	-2.4	-3.4	-4.7
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.2	-0.2
Before-tax Corporate Profits																		
WITHBASE	75.5	86.5	100.8	126.0	136.9	132.1	166.2	193.1	224.3	256.2	245.6	230.7	265.4	295.3	313.2	391.4	403.6	433.2
WITHLOW	75.5	86.5	100.8	126.0	136.9	132.1	166.2	193.1	224.3	256.2	245.6	230.2	264.3	294.7	313.9	393.6	405.7	435.8
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.1	0.6	-0.7	-2.2	-2.1	-2.6
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.2	-0.2	-0.5	-0.5	-0.6
Aftertax Corporate Profits																		
WITHBASE	41.3	49.0	59.1	76.8	85.3	81.5	102.4	120.3	140.9	168.3	164.3	152.1	173.3	193.2	206.0	254.4	264.8	285.1
WITHLOW	41.3	49.0	59.1	76.8	85.3	81.5	102.4	120.3	140.9	168.3	164.3	151.7	172.4	192.4	205.8	254.9	265.0	285.3
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.8	0.8	0.2	-0.5	-0.2	-0.2
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5	0.4	0.1	-0.2	-0.1	-0.1
Real Aftertax Profits (79$)																		
WITHBASE	76.5	86.7	100.6	125.2	125.5	105.8	127.1	140.8	153.0	168.3	150.7	128.5	133.5	136.4	134.3	152.7	146.9	146.7
WITHLOW	76.5	86.7	100.6	125.2	125.5	105.8	127.1	140.8	153.0	168.3	150.7	128.2	132.9	136.1	134.6	153.6	147.9	148.1
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5	0.3	-0.3	-1.0	-1.0	-1.4
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.2	-0.2	-0.6	-0.7	-0.9
Other Indicators																		
State & Local Gov't Bond Rate (%)																		
WITHBASE	6.12	5.22	5.04	5.00	5.90	6.43	5.66	5.20	5.52	5.93	7.86	8.76	9.00	8.42	8.08	8.42	8.36	8.08
WITHLOW	6.12	5.22	5.04	5.00	5.90	6.43	5.66	5.20	5.52	5.93	7.86	8.75	8.95	8.34	7.96	8.27	8.19	7.87
DIFF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.09	0.12	0.15	0.18	0.21
%DIFF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.51	1.03	1.48	1.76	2.16	2.60
Unemployment Rate (%)																		
WITHBASE	5.0	6.0	5.6	4.8	5.6	8.5	7.7	7.0	6.0	5.8	7.2	7.8	7.1	7.0	7.0	6.5	6.3	6.2
WITHLOW	5.0	6.0	5.6	4.8	5.6	8.5	7.7	7.0	6.0	5.8	7.2	7.8	7.2	7.2	7.2	6.7	6.5	6.5
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.5	-1.2	-1.7	-2.1	-2.7	-3.4	-4.1
Industrial Production Index (79=1.000)																		
WITHBASE	0.707	0.718	0.785	0.851	0.848	0.772	0.854	0.906	0.959	1.000	0.963	0.977	1.059	1.105	1.151	1.229	1.258	1.292
WITHLOW	0.707	0.718	0.785	0.851	0.848	0.772	0.854	0.906	0.959	1.000	0.963	0.977	1.058	1.105	1.155	1.233	1.262	1.298
DIFF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	-0.002	-0.004	-0.004	-0.006
%DIFF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.016	0.061	-0.021	-0.177	-0.298	-0.346	-0.444

Table 9
Estimated Impact of Incremental Pollution Control Costs, 1970-1987
Constant Money Supply

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Gross National Product																		
WITHBASE	992.8	1077.6	1186.3	1327.2	1435.3	1549.9	1718.7	1920.2	2159.6	2417.9	2632.7	2924.7	3318.0	3732.5	4180.7	4737.2	5268.7	5847.0
OFFSET	992.8	1076.6	1184.3	1323.9	1430.8	1544.7	1712.0	1911.5	2148.9	2401.3	2612.1	2897.9	3278.2	3679.6	4113.0	4653.6	5167.3	5722.3
DIFF	0.0	1.0	2.0	3.3	4.4	5.2	6.7	8.6	10.7	16.6	20.6	26.8	39.8	53.0	67.7	83.5	101.3	124.7
%DIFF	0.0	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.7	0.8	0.9	1.2	1.4	1.6	1.8	2.0	2.2
Real GNP (79$)																		
WITHBASE	1770.5	1830.6	1934.8	2047.2	2034.8	2011.9	2119.9	2237.3	2344.5	2417.9	2414.6	2428.6	2510.3	2582.5	2669.9	2780.0	2849.4	2927.3
OFFSET	1770.5	1829.3	1932.8	2045.2	2033.4	2011.2	2118.9	2236.0	2343.0	2414.4	2411.2	2424.3	2502.7	2573.6	2660.6	2771.9	2841.2	2918.0
DIFF	0.0	1.3	2.0	2.0	1.4	0.7	0.9	1.4	1.5	3.4	3.4	4.3	7.6	8.9	9.3	8.0	8.2	9.3
%DIFF	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Annual Rate of Change																		
WITHBASE	-0.2	3.4	5.7	5.8	-0.6	-1.1	5.4	5.5	4.8	3.1	-0.1	0.6	3.4	2.9	3.4	4.1	2.5	2.7
OFFSET	-0.2	3.3	5.7	5.8	-0.6	-1.1	5.4	5.5	4.8	3.0	-0.1	0.5	3.2	2.8	3.4	4.2	2.5	2.7
DIFF	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	-0.1	0.0	0.0
%DIFF	0.0	2.2	0.6	-0.1	5.2	2.8	0.1	0.3	0.1	2.6	0.4	6.8	4.0	1.5	0.2	-1.5	-0.1	1.1
Prices ------																		
Implicit Price Deflator (79=1.000)																		
WITHBASE	0.561	0.589	0.613	0.648	0.705	0.770	0.811	0.858	0.921	1.000	1.090	1.204	1.322	1.445	1.566	1.704	1.849	1.997
OFFSET	0.561	0.589	0.613	0.647	0.704	0.768	0.808	0.855	0.917	0.995	1.083	1.195	1.310	1.430	1.546	1.679	1.819	1.961
DIFF	0.000	0.000	0.000	0.001	0.002	0.002	0.003	0.003	0.004	0.005	0.007	0.009	0.012	0.016	0.020	0.025	0.030	0.036
%DIFF	0.000	0.020	0.066	0.151	0.241	0.296	0.347	0.391	0.432	0.550	0.645	0.745	0.908	1.091	1.292	1.500	1.668	1.854
Wholesale Price Index (79=1.000)																		
WITHBASE	0.467	0.483	0.504	0.571	0.678	0.741	0.776	0.823	0.888	1.000	1.141	1.290	1.451	1.624	1.775	1.949	2.147	2.347
OFFSET	0.467	0.482	0.503	0.569	0.675	0.737	0.771	0.819	0.882	0.992	1.130	1.276	1.432	1.598	1.741	1.907	2.097	2.287
DIFF	0.000	0.000	0.001	0.001	0.003	0.004	0.004	0.005	0.006	0.008	0.011	0.014	0.019	0.026	0.033	0.042	0.050	0.060
%DIFF	0.000	0.033	0.110	0.256	0.427	0.502	0.534	0.581	0.617	0.786	0.956	1.073	1.310	1.596	1.904	2.185	2.385	2.611
Consumer Price Index (79=1.000)																		
WITHBASE	0.534	0.556	0.575	0.611	0.678	0.740	0.783	0.814	0.898	1.000	1.134	1.265	1.394	1.527	1.654	1.796	1.949	2.107
OFFSET	0.534	0.556	0.575	0.610	0.677	0.739	0.781	0.811	0.895	0.996	1.129	1.257	1.384	1.513	1.637	1.774	1.923	2.076
DIFF	0.000	0.000	0.000	0.001	0.001	0.002	0.002	0.003	0.003	0.004	0.006	0.007	0.010	0.013	0.018	0.022	0.026	0.032
%DIFF	0.000	0.001	0.042	0.100	0.101	0.239	0.274	0.311	0.346	0.414	0.495	0.583	0.736	0.891	1.075	1.235	1.374	1.526
Annual Rate of Change																		
WITHBASE	5.9	4.2	3.3	6.3	11.1	9.1	5.7	6.5	7.8	11.3	13.4	11.5	10.2	9.5	8.4	8.6	8.5	8.1
OFFSET	5.9	4.2	3.3	6.2	11.0	9.1	5.7	6.5	7.7	11.2	13.4	11.4	10.1	9.3	8.2	8.4	8.4	8.0
DIFF	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.1	0.2
%DIFF	0.0	0.0	1.1	1.0	0.8	0.7	0.7	0.6	0.5	0.7	0.7	0.9	1.7	1.8	2.4	2.0	1.8	2.0
Investment ----------																		
Real Business Fixed Investment (79$)																		
WITHBASE	195.5	192.6	207.9	237.2	233.1	204.7	215.2	241.1	261.5	280.4	270.5	262.9	276.8	291.4	305.8	321.9	339.5	349.9
OFFSET	195.5	192.4	207.5	236.7	232.7	204.4	215.0	241.0	261.1	279.9	269.7	262.1	275.3	289.3	303.6	320.2	338.5	349.1
DIFF	0.0	0.2	0.4	0.5	0.4	0.3	0.2	0.1	0.1	0.5	0.7	0.8	1.5	2.0	2.2	1.7	1.1	0.8
%DIFF	0.0	0.1	0.2	0.2	0.2	0.1	0.1	0.0	0.1	0.2	0.1	0.1	0.6	0.7	0.7	0.5	0.3	0.2

Table 9 (Continued)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Producers' Durable Equipment																		
WITHBASE	111.9	111.0	123.1	145.3	147.5	129.7	137.6	160.0	174.3	181.8	175.2	171.0	179.9	190.0	199.4	211.3	222.1	229.9
OFFSET	111.9	110.9	122.8	145.0	147.2	129.6	137.6	160.0	174.2	181.6	174.8	170.5	179.0	188.8	198.2	210.5	221.7	229.8
DIFF	0.0	0.1	0.3	0.3	0.2	0.1	0.0	0.0	0.0	0.3	0.4	0.5	0.9	1.2	1.2	0.9	0.4	0.2
%DIFF	0.0	0.1	0.2	0.2	0.2	0.1	0.0	0.0	0.0	0.1	0.3	0.3	0.5	0.6	0.6	0.4	0.2	0.1
Nonresidential Construction																		
WITHBASE	87.4	85.2	88.0	94.3	86.9	76.1	78.4	80.6	88.8	96.5	95.8	92.3	97.3	101.5	106.6	112.8	117.5	119.8
OFFSET	87.4	85.2	87.8	94.1	86.7	76.0	78.3	80.5	88.7	96.3	95.5	91.9	96.6	100.7	105.6	111.9	116.8	119.1
DIFF	0.0	0.0	0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.2	0.3	0.4	0.7	0.8	1.0	0.9	0.7	0.7
%DIFF	0.0	0.1	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.2	0.3	0.4	0.7	0.8	0.9	0.8	0.6	0.6
Housing Starts (mil. units)																		
WITHBASE	1.44	2.04	2.36	2.05	1.33	1.16	1.53	1.97	2.01	1.72	1.32	1.40	1.84	1.77	1.82	2.06	2.06	2.09
OFFSET	1.44	2.02	2.34	2.02	1.31	1.15	1.53	1.96	1.99	1.69	1.30	1.35	1.77	1.70	1.75	2.00	2.01	2.04
DIFF	0.00	0.02	0.03	0.03	0.02	0.01	0.01	0.01	0.02	0.04	0.03	0.05	0.08	0.07	0.08	0.06	0.06	0.05
%DIFF	0.00	1.06	1.08	1.29	1.62	0.58	0.35	0.49	0.87	2.11	2.14	3.85	4.30	4.40	4.45	2.98	2.75	2.69
Trade -----																		
Real Imports (79$)																		
WITHBASE	163.6	170.4	188.6	201.0	198.3	175.3	207.8	224.2	251.2	268.4	266.5	266.4	283.9	297.9	307.0	323.4	336.0	344.7
OFFSET	163.6	170.2	188.2	200.6	198.1	175.2	208.0	224.3	251.2	268.2	265.8	266.1	282.6	296.1	305.0	322.1	335.5	344.4
DIFF	0.0	0.2	0.4	0.5	0.2	0.0	-0.2	-0.1	0.0	0.1	0.7	0.3	1.3	1.9	2.0	1.3	0.5	0.3
%DIFF	0.0	0.1	0.2	0.2	0.1	0.0	-0.1	-0.1	0.0	0.0	0.2	0.1	0.5	0.6	0.7	0.4	0.2	0.1
Real Exports (79$)																		
WITHBASE	135.3	136.2	140.7	186.7	200.2	198.7	211.3	217.2	244.7	281.8	309.9	308.8	323.1	338.1	348.5	356.3	360.1	371.7
OFFSET	135.3	136.2	140.7	186.8	200.3	198.8	211.3	217.2	244.7	281.9	310.2	309.1	323.3	338.3	348.6	356.1	359.4	370.6
DIFF	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	-0.1	-0.3	-0.2	-0.1	-0.1	0.0	0.2	0.7	1.1
%DIFF	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	0.0	0.1	0.2	0.3
Real Consumption (79$) ---- ----------- -----																		
Motor Vehicles & Parts																		
WITHBASE	59.2	70.6	81.3	87.6	72.9	73.4	88.7	98.4	101.9	95.6	83.1	86.9	96.5	95.8	103.2	109.6	111.4	114.2
OFFSET	59.2	70.4	81.1	87.4	72.8	73.3	88.6	98.2	101.7	95.3	82.6	86.6	95.7	94.8	102.2	109.1	110.7	113.3
DIFF	0.0	0.2	0.2	0.2	0.1	0.1	0.1	0.2	0.2	0.2	0.6	0.4	0.8	1.0	1.0	0.5	0.7	0.8
%DIFF	0.0	0.2	0.2	0.3	0.1	0.2	0.1	0.2	0.2	0.2	0.7	0.4	0.9	1.1	1.0	0.5	0.6	0.7
Other Durables																		
WITHBASE	70.2	72.6	80.9	89.4	90.1	89.8	95.4	103.3	111.3	117.0	112.8	114.6	119.0	123.6	131.1	139.0	143.3	148.3
OFFSET	70.2	72.5	80.8	89.3	89.9	89.7	95.2	103.0	110.9	116.5	112.2	113.8	117.8	122.1	129.2	137.1	141.2	146.0
DIFF	0.0	0.1	0.1	0.2	0.2	0.1	0.2	0.3	0.4	0.6	0.6	0.8	1.2	1.6	1.8	1.9	2.1	2.4
%DIFF	0.0	0.1	0.2	0.2	0.2	0.1	0.2	0.3	0.4	0.5	0.6	0.7	1.0	1.3	1.4	1.4	1.5	1.6
Nondurables																		
WITHBASE	482.8	491.2	511.6	524.1	516.1	524.4	548.5	568.2	588.3	601.2	608.2	605.4	610.6	620.4	633.0	648.1	660.1	672.4
OFFSET	482.8	491.1	511.5	524.1	516.3	524.7	548.8	568.5	588.5	601.4	608.5	606.0	610.9	620.7	633.5	648.9	661.2	673.8
DIFF	0.0	0.1	0.1	0.0	-0.2	-0.3	-0.3	-0.3	-0.2	-0.2	0.3	-0.6	-0.3	-0.4	-0.5	-0.8	-1.2	-1.4
%DIFF	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2
Services																		
WITHBASE	485.7	503.0	527.9	550.5	564.7	583.0	607.9	635.4	670.0	697.2	715.4	735.1	754.5	777.3	806.2	837.9	867.1	896.5
OFFSET	485.7	502.8	527.7	550.1	564.3	582.7	607.5	634.9	669.5	696.4	714.4	733.9	752.7	775.0	803.5	835.1	864.0	893.1
DIFF	0.0	0.1	0.3	0.4	0.4	0.4	0.4	0.5	0.5	0.8	1.1	1.1	1.8	2.3	2.7	2.8	3.1	3.4
%DIFF	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.4	0.4

Table 9 (Continued)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Incomes																		

Disposable Income																		
WITHBASE	695.3	751.8	810.4	914.9	999.0	1096.7	1195.1	1312.8	1464.8	1644.2	1824.9	2038.4	2303.8	2580.6	2888.4	3239.9	3599.4	3987.1
OFFSET	695.3	751.4	809.7	913.5	996.8	1094.0	1191.5	1308.3	1459.3	1635.8	1814.4	2025.1	2284.7	2554.9	2854.8	3196.6	3546.3	3972.0
DIFF	0.0	0.3	0.7	1.4	2.2	2.7	3.5	4.5	5.5	8.4	10.5	13.3	19.1	25.7	33.6	43.3	53.0	65.1
%DIFF	0.0	0.0	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.8	1.0	1.2	1.4	1.5	1.7
Real Disposable Income (79$)																		
WITHBASE	1221.7	1266.8	1317.3	1406.9	1395.5	1423.4	1474.6	1527.6	1595.5	1643.9	1654.9	1672.2	1723.4	1766.6	1826.4	1894.4	1946.4	1998.8
OFFSET	1221.7	1266.4	1316.7	1406.4	1395.4	1423.8	1475.0	1528.0	1595.8	1643.4	1654.8	1672.3	1722.6	1765.7	1825.7	1894.4	1947.1	1999.8
DIFF	0.0	0.4	0.5	0.4	0.1	-0.4	-0.3	-0.4	0.3	0.4	0.1	-0.2	0.8	0.9	0.7	0.0	-0.7	-1.0
%DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Before-tax Corporate Profits																		
WITHBASE	75.5	86.5	100.8	126.0	136.9	132.1	166.2	193.1	224.3	256.2	245.6	230.7	265.4	295.3	313.2	391.4	403.6	433.2
OFFSET	75.5	86.1	100.0	124.7	135.6	131.0	165.0	191.5	222.4	252.5	241.7	226.0	257.3	285.8	302.5	380.6	392.4	419.4
DIFF	0.0	0.4	0.8	1.3	1.3	1.1	1.2	1.5	1.9	3.8	3.9	4.7	8.0	9.5	10.7	10.8	11.2	13.8
%DIFF	0.0	0.5	0.8	1.0	1.0	0.8	0.7	0.8	0.9	1.5	1.6	2.1	3.1	3.3	3.5	2.8	2.9	3.3
Aftertax Corporate Profits																		
WITHBASE	41.3	49.0	59.1	76.8	85.3	81.5	102.4	120.3	140.9	168.3	164.3	152.1	173.3	193.2	206.0	254.4	264.8	285.1
OFFSET	41.3	48.8	58.6	76.0	84.5	80.9	101.7	119.4	139.8	165.9	161.8	149.1	168.3	187.2	199.3	247.5	257.6	276.2
DIFF	0.0	0.2	0.5	0.8	0.8	0.6	0.7	0.9	1.2	2.4	2.5	3.0	5.0	5.9	6.7	6.9	7.2	8.8
%DIFF	0.0	0.5	0.8	1.0	0.9	0.8	0.7	0.8	0.8	1.4	1.5	2.0	3.0	3.2	3.4	2.8	2.8	3.2
Real Aftertax Profits (79$)																		
WITHBASE	76.5	86.7	100.6	125.2	125.5	105.8	127.1	140.8	153.0	168.3	150.7	128.5	133.5	136.4	134.3	152.7	146.9	146.7
OFFSET	76.5	86.3	99.9	124.2	124.8	105.4	126.8	140.4	152.5	167.0	149.6	127.1	131.1	134.0	132.0	151.4	145.9	145.5
DIFF	0.0	0.4	0.7	1.0	0.8	0.4	0.3	0.4	0.5	1.3	1.1	1.3	2.4	2.4	2.3	1.3	1.0	1.2
%DIFF	0.0	0.5	0.7	0.8	0.6	0.4	0.3	0.3	0.3	0.8	0.8	1.1	1.8	1.8	1.7	0.9	0.7	0.8
Other Indicators																		
----- ----------																		
State & Local Gov't Bond Rate (%)																		
WITHBASE	6.12	5.22	5.04	5.00	5.90	6.43	5.66	5.20	5.52	5.93	7.06	8.76	9.00	8.42	8.08	8.42	8.36	8.08
OFFSET	6.12	5.22	5.04	4.99	5.90	6.41	5.65	5.19	5.52	5.93	7.04	8.76	8.98	8.38	8.02	8.35	8.30	8.02
DIFF	0.00	-0.01	0.00	0.01	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.02	0.04	0.06	0.07	0.06	0.06
%DIFF	0.00	-0.11	-0.09	0.11	0.13	0.27	0.25	0.21	0.11	-0.06	0.13	0.09	0.27	0.48	0.69	0.78	0.73	0.73
Unemployment Rate (%)																		
WITHBASE	5.0	6.0	5.6	4.8	5.6	8.5	7.7	7.0	6.0	5.8	7.2	7.8	7.1	7.0	7.0	6.5	6.3	6.2
OFFSET	5.0	6.0	5.6	4.9	5.6	8.5	7.7	7.0	6.0	5.8	7.2	7.8	7.2	7.1	7.1	6.6	6.3	6.3
DIFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
%DIFF	0.0	-0.2	-0.6	-0.6	-0.4	-0.1	-0.1	-0.2	-0.2	-0.5	-0.6	-0.5	-1.1	-1.4	-1.4	-1.2	-1.0	-1.1
Industrial Production Index (79=1.000)																		
WITHBASE	0.707	0.718	0.785	0.851	0.848	0.772	0.854	0.906	0.959	1.000	0.963	0.977	1.059	1.105	1.153	1.229	1.258	1.292
OFFSET	0.707	0.717	0.784	0.850	0.847	0.771	0.854	0.905	0.958	0.997	0.960	0.974	1.053	1.097	1.146	1.224	1.252	1.286
DIFF	0.000	0.001	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.003	0.003	0.003	0.006	0.007	0.007	0.006	0.005	0.006
%DIFF	0.000	0.148	0.211	0.193	0.117	0.066	0.064	0.103	0.110	0.268	0.319	0.320	0.604	0.662	0.648	0.459	0.419	0.488

Table 10
Comparison of Alternative Simulations

	With Base Case	With Holding Money Supply Constant	With High Cost	With Low Cost	Without
Real GNP (Billions 79$)					
Level in 1980	2414.6	2411.2	2415.3	2414.6	2415.9
Level in 1987	2927.3	2918.0	2930.5	2928.9	2949.1
Growth Rate 1970-1987	3.0	3.0	3.0	3.0	3.1
Implicit Price Deflator (1979=1)					
Level in 1980	1.090	1.083	1.090	1.090	1.059
Level in 1987	1.997	1.961	2.000	1.980	1.860
Growth Rate 1970-1987	7.8	7.6	7.8	7.7	7.3
Unemployment Rate (%)					
Level in 1980	7.2	7.2	7.2	7.2	7.5
Level in 1987	6.2	6.3	6.2	6.5	6.7
Business Fixed Investment (Billions 79$)					
Level in 1980	270.5	269.7	270.5	270.5	268.4
Level in 1987	349.9	349.1	350.5	344.3	349.0

COMPARISONS OF ESTIMATED AND ACTUAL POLLUTION CONTROL COST FOR SELECTED INDUSTRIES

Prepared for

Office of Planning & Evaluation
U.S. Environmental Protection Agency

Prepared by

Putnam, Hayes & Bartlett, Inc.

February 1980

COMPARISONS OF ESTIMATED AND ACTUAL POLLUTION CONTROL COST FOR SELECTED INDUSTRIES

SUMMARY AND OVERVIEW

Introduction

Federal environmental regulations have experienced significant growth in the 1970's. The costs of these regulations are an issue of intense interest and controversy to both industry and the government. The Environmental Protection Agency (EPA) has routinely developed estimates of pollution control costs and their economic impact for every major regulation. It often has been suggested that EPA compare its cost forecasts with actual expenditure data. The purpose of this report is to compare estimates of pollution abatement costs prepared by EPA, by EPA contractors, by industry, and by independent groups with reported expenditures.[1] Pollution abatement capital cost estimates for specific regulations were compared with reported capital expenditures for the following six industries.

- Steam Electric Utilities -- BPT effluent guidelines
- Electric Utility Flue Gas Desulfurization Systems -- Scrubbers
- Pulp and Paper -- BPT effluent guidelines
- Petroleum Refining -- BPT effluent guidelines
- Iron and Steel -- BPT effluent guidelines
- Automobiles -- Light duty vehicle air pollution controls.

For each industry and regulation several estimates are provided including an EPA and industry estimate developed at about the time that the regulations were promulgated. In several cases a number of other estimates are given from other sources such as the National Academy of Science, the National Commission on Water Quality, the EPA Cost of Clean Air and Water report to Congress, and so forth. Actual expenditure data are taken from a variety of sources including surveys from the Census Bureau, the Department of Commerce/Bureau of Economic Analysis, McGraw-Hill, the Bureau of Labor Statistics, and industry trade associations. In cases where three or more sources of actual expenditure data are available, usually one source was significantly different than the others. For example, the McGraw-Hill survey reported substantially higher figures in the iron and steel industry and pulp and paper industry than the other sources. In the petroleum refining industry, the BEA survey was considerably higher than the other surveys.

---

[1] Expenditure forecasts designated as an "industry estimate" refer to studies prepared or sponsored by individual firms, industry trade associations, or by a loose collection of firms such as the Utility Water Act Group.

Methodology

When comparing EPA and industry cost forecasts with actual expenditures a number of adjustments were made. First, forecasted expenditure studies usually project only incremental costs due to federal regulations and do not account for: (1) construction work in progress -- these costs are included in the year when the plant is placed in service; (2) pollution control costs voluntarily incurred, for example, for economic reasons; (3) costs associated with state and local requirements. As these costs are included in the survey of actual expenditures they had to be added back into the EPA and industry forecasts. A second major adjustment was to scale forecasted expenditures by the actual compliance rate.[1] Finally, for each industry all figures were converted to constant dollars using the appropriate pollution control deflator.

---

[1] In the case of automobile pollution controls and electric utility scrubbers, these adjustments were not made because actual expenditures were reported on a unit basis (e.g., dollars per car or dollars per kilowatt).

Summary of Results

Table 1 compares EPA and industry capital cost estimates with actual expenditures for five industries. (Please refer to the appropriate industry section for a discussion of the expenditure forecasts, actual expenditure data, forecasts by independent groups, key assumptions, and so forth.) This table illustrates several trends. First, for four of the five industries examined the EPA estimates are lower than the industry estimates. However, for refineries it is only the most recent EPA Cost of Clean Air and Water report which is lower than the industry estimate. Second, both EPA and industry forecasts tend to overestimate compliance costs more often than they underestimate these costs. For example, EPA forecasts (excluding the Cost of Clean forecasts) range from 26 percent below to 156 percent above reported expenditures, while industry forecasts range from 25 percent below to 247 percent above reported expenditures. If this trend to overestimate compliance costs were further substantiated by looking at a larger sample of industries and including operating costs, it could have implications for EPA decision-making, particularly for decisions requiring a balancing of benefits and costs.

When comparing expenditure forecasts to reported expenditures, EPA forecasts are closer to the actual figures for the iron and steel industry and for electric utilities; industry estimates are closer for the pulp and paper industry and for electric utility scrubbers, while the forecasted expenditures for the refining industry are about the same.

Table 2 compares estimates of automotive pollution control price increases with actual sticker price increases. These data

TABLE 1

RATIO OF EXPENDITURE FORECASTS TO ACTUAL EXPENDITURES[1,2]

Expenditure Forecasts	1974-1977	1975-1977	1972-1977
Utilities (BPT Guidelines)			
EPA	.89-.91		
Industry	1.36-1.40		
Electric Utility Scrubbers[3]			
EPA	.74		
Industry	.91		
Pulp and Paper (BPT Guidelines)			
EPA	1.27-1.49		
Cost of Clean[4]			1.14
Industry			.75
Refineries (BPT Guidelines)			
EPA	1.87-2.5		
Cost of Clean[4]			1.82-1.84
Industry	1.91-2.62		
Iron and Steel (BPT Guidelines)			
EPA		1.32-1.79	
Cost of Clean[4]			.55- .85
Industry		2.56-3.47	

---

[1] These ratios are forecasted expenditures divided by actual expenditures.

[2] The range of values reflects comparisons with several expenditure surveys.

[3] These are composite figures representing comparisons including scrubbers installed on new units and scrubbers retrofitted on existing units on a 21 plant sample. (See Section II for more details.)

[4] *The Cost of Clean Air and Water*, Report to Congress, August 1979.

TABLE 2

RATIO OF ESTIMATED TO
ACTUAL STICKER PRICE INCREASES

	ACTUAL PRICE INCREASES[1]	
	BIS Data	Manufacturers' Data
Model Year 1973-1974		
EPA Estimate	1.32-1.45	1.54-1.69
Industry Estimate	.72-1.74	.85-2.03
Model Year 1975-1976		
EPA Estimate	.93-1.02	.95-1.05
Industry Estimate	.51-2.31	.53-2.37
Model Year 1980		
EPA Estimate	.82	

---

[1] These price increases are that portion of the reported price increases which are attributable to addition or improvement of pollution control equipment.

indicate that EPA estimates are closer to the actual price increases than the industry estimates. The manufacturers' estimates indicate a large degree of variance; however, since individual manufacturer estimates were not given in this data source, it is impossible to determine if they overestimate control costs without knowing if the higher estimates are from the larger manufacturers.

Finally, in comparing EPA and industry national aggregate cost forecasts, differences in these forecasts result from a combination of different assumptions regarding unit control costs, the amount of capacity affected, the industrial growth rate, and the assumed rate of implementation of the program. A more in-depth review of the cost studies is needed to identify the key assumptions responsible for the disparate EPA and industry estimates. However, for the steam electric BPT guidelines some information is available. The industry unit cost estimates for non-nuclear plants complying with the chemical guidelines were three times higher than EPA's estimates. Additionally, industry projected higher capacity growth rates. Taken together, these two assumptions result in an industry estimate 70 percent higher than EPA's estimate. Even assuming EPA's growth rate, the industry's higher unit cost factors result in an estimated cost of compliance 53 percent higher than EPA estimates.

I. EFFLUENT GUIDELINES FOR STEAM ELECTRIC POWER PLANTS

Introduction

The effluent guidelines for steam electric powerplants promulgated on October 8, 1974 included three categories: thermal guidelines, chemical guidelines, and the entrainment regulations. The thermal guidelines require: (1) all new units to install closed cycle cooling when placed in service, and (2) all units greater than 500 MW and placed in service between 1 January 1970 and 1 January 1974 to retrofit from open cycle to closed cycle cooling by 1 July 1981. The chemical guidelines limit pH levels, suspended solids, oil and grease, metals, chlorine and certain other pollutants in waste streams. Initial limitations went into effect in 1977 and more stringent requirements are to go in effect in 1983. The entrainment regulations require the location, design and construction of cooling water intake structures to reflect the best available technology for minimizing environmental impact. Since capital expenditures due to the entrainment regulations are not expected until after 1980, they are not included in this analysis.

Methodology and Data Sources

In this analysis EPA and industry estimates were compared with two expenditure surveys. The EPA estimates were prepared by Temple, Barker & Sloane, Inc.;[1] the National Economic Research Associates[2] prepared estimates for industry (Utility Water Act

---

[1] Economic Analysis of Effluent Guidelines: Steam Electric Powerplants, December 1974.

[2] Utility Water Act Group Economic Analysis submitted as comments to the proposed effluent guidelines for steam electric powerplants, June 1974.

Group), and actual expenditure data were given in the McGraw-Hill survey[1] and the Bureau of Economic Analysis survey.[2] The EPA and industry studies used a different accounting procedure to tabulate capital expenditures than the survey data. To make these sources compatible certain adjustments were made to the EPA and industry expenditure forecasts. These studies projected the incremental costs due to federal regulation and they did not account for: (1) costs voluntarily incurred, for example, because of economic reasons; (2) costs of construction work in progress -- these costs were included in the year when the unit was expected to be placed in service; (3) costs associated with state and local requirements. As the McGraw-Hill and BEA data report total pollution abatement expenditures, the types of expenditures listed above had to be added back into the EPA and industry forecasts.

Another major adjustment was to scale the expenditure estimates by the 68% compliance rate reported by the EPA Office of Enforcement. Further, the industry study forecasted capital expenditures only for the 1974-1983 period. Estimates for the 1974-1977 period were developed by assuming the distribution of costs in time would be the same as in the EPA study. This assumption is reasonable when similar industrial growth rates and capacity installation rates are used. Finally, all figures were adjusted to 1974 dollars using the Census Bureau's new plant and equipment price deflator for water pollution abatement equipment.

---

[1] Historical Pollution Control Expenditures and Related Data, McGraw-Hill, November 1979.

[2] "Capital Expenditures by Business for Pollution Abatement", Survey of Current Business, July 1975, June 1977, June 1979.

Cost Comparisons

Table 3 compares EPA and industry (UWAG) capital cost factors on a dollars/kilowatt basis. EPA's estimates are only slightly lower than industry's estimates for the thermal guidelines. However, for the chemical guidelines, EPA's non-nuclear estimate is less than one third of the corresponding industry estimate while the nuclear estimates are about the same. Table 4 compares EPA and industry capital expenditure estimates for water pollution abatement equipment with actual expenditures reported for the years 1974-1977. The EPA estimates are slightly lower than actual expenditures while the industry estimates are considerably higher (see chart below).

RATIO OF ESTIMATED CAPITAL
EXPENDITURES TO REPORTED
CAPITAL EXPENDITURES

	Actual Expenditures	
Estimated Expenditures	McGraw-Hill	DOC/BEA
EPA	.91	.89
UWAG	1.40	1.36

Differences in EPA and UWAG projected capital expenditures for water pollution control equipment result from differences in two key assumptions in their financial models. First, UWAG and EPA used different capital cost factors as shown in Table 3. Second, UWAG does not agree with the future industry growth rates assumed in the EPA study. The EPA assumptions were developed by the National Power Survey's Technical Advisory Committee on Finance. UWAG projected higher industry growth rates than EPA approaching historical rates observed in the past. (A later EPA study in May 1976 revised downward the total capital expenditure estimates given in this study because even lower growth rates were predicted which means fewer new plants would be built than

TABLE 3

COMPARISON OF EPA AND UTILITY WATER ACT GROUP CAPITAL COST FACTORS
(Expressed in 1972 Dollars/Kilowatt)

	EPA ESTIMATE	UWAG ESTIMATE
Thermal Guidelines		
For Retrofitted Units		
Non-Nuclear	$20.43	$22.44
Nuclear	$24.58	$27.01
For New Units		
Non-Nuclear	$ 4.89	$ 6.40
Nuclear	$ 3.84	$ 4.27
Chemical Guidelines[1]		
Capacity prior to 1974		
Non-Nuclear	$ 1.70	$ 5.78
Nuclear	$ 0.58	$ 0.53
Capacity 1974-1978		
Non-Nuclear	$ 1.29	$ 4.58
Nuclear	$ 0.58	$ 0.53

---

[1] The estimates are the projected costs to meet the 1977 BPT chemical guidelines.

had previously been expected.) The UWAG estimates in Table 4 reflect just the higher capital cost factors and not the higher growth rate in electrical generation capacity. Using the UWAG assumed growth rate and capital cost factors, the expenditures are projected to be $2.9 billion for the 1974-1977 period. These figures are 52-56% higher than actual expenditures.

TABLE 4

CAPITAL EXPENDITURES FOR 1977 BPT GUIDELINES
(Billions of 1974 Dollars)

	1974-77	1974-83
EXPENDITURE FORECASTS		
EPA - DECEMBER 1974 (Economic Analysis of Effluent Guidelines Steam Electric Powerplants)	1.7[1]	6.6
UWAG[2] - JUNE 1974 (UWAG Economic Analysis was prepared by National Economic Research Associates, Inc.)	2.6[1]	8.9
ACTUAL FORECASTS		
McGRAW-HILL - NOVEMBER 1979 (Historical Pollution Control Expenditures and Related Data)	1.86[3]	--
DOC - BUREAU OF ECONOMIC ANALYSIS (Capital Expenditures by Business for Pollution Abatement)	1.91[3]	--

---

[1] The 1974-1977 estimates have been adjusted from that reported in their respective studies to include construction work in progress, pollution abatement expenditures incurred voluntarily (e.g., for economic reasons), and a compliance rate of 68%.

[2] This expenditure estimate assumes only the higher UWAG capital cost factors shown in the previous table, and not the higher growth rate in electrical capacity.

[3] This figure has been adjusted to 1974 dollars using the Census Bureaus' new plant and equipment price deflator for water pollution abatement equipment.

II. ELECTRIC UTILITY FLUE GAS DESULFURIZATION SYSTEMS (SCRUBBERS)

Introduction

The 1970 Clean Air Act amendments required EPA to develop National Ambient Air Quality Standards. The states were required to implement measures to assure the standards would be attained. As fossil fuel electric powerplants are among the largest sources of air pollution, much effort was directed at controlling these sources. Rather than focus on the total cost of this program we have chosen to examine the costs of scrubbing sulfur dioxide emissions -- one of the most controversial elements of EPA's program.

Methodology and Data Sources

In the analysis below, all cost estimates and reported expenditures are compared on a unit (dollars/kilowatt) basis rather than on an aggregate basis. Actual costs for the period 1970-1978 are reported in a recent EPA study[1] which summarized capital expenditures from 21 plants that have installed flue gas desulfurization (FGD) on 10,981 MW of generation capacity. The expenditures cover just the sulfur dioxide portion of the emission control system and were adjusted to 1977 dollars. The EPA cost estimates were taken from a report prepared for EPA by Temple, Barker & Sloane, Inc., in May 1976.[2] Industry estimates were prepared by the National Economic Research Associates.[1] The National Public Hearings on Powerplant Compliance with Sulfur Oxide Air Pollution Regulations was another source of cost estimates.[2] All cost estimates and expenditures were adjusted to 1977 dollars using the Chemical Engineering Index.

---

[1] Utility FGD Costs: Reported and Actual Costs for Operating FGD Systems. PEDCO, 1978.

[2] Economic and Financial Impacts of Air and Water Pollution Controls on the Electric Utility Industry. Temple, Barker & Sloane, Inc., 1976.

Cost Comparisons

Table 5 compares EPA and industry cost estimates with reported capital expenditures for sulfur dioxide (SO_2) scrubbers. The reported capital expenditures are averages from the 21 plant sample. The observed spectrum of control costs ranged from $67-$118/KW for new units and from $56-$233/KW for retrofitting existing units. EPA estimates are lower than industry estimates and both are lower than average reported expenditures. The chart below summarizes the differences between scrubbing cost estimates and the reported average expenditures. The industry's estimate of the retrofit cost agrees quite closely with the actual reported expenditures, while EPA's estimate was 77 percent of actual reported expenditures. Industry underestimated the costs of scrubbers on new plants by 16 percent, while EPA underestimated the costs by 30 percent.

RATIO OF SCRUBBING COST
ESTIMATES TO REPORTED EXPENDITURES

	New Unit Cost	Retrofit Cost
EPA	.70	.77
National Public Hearings	--	.69-.89
Industry	.84	.96

---

[1] The Cost of Reducing SO_2 Emissions from Electric Utility Plants. NERA, June 1975.

[2] Report of the Hearing Panel, National Public Hearings on Powerplant Compliance with Sulfur Oxide Air Pollution Regulations, October 18, 1973 to November 2, 1973.

Since the costs are being compared on a unit basis, one would expect the costs to be in fairly close agreement. However, the EPA costs are substantially lower. Using the EPA cost factors and the PEDCO 21 plant sample, EPA would have estimated the capital expenditures to be 26 percent (or $234 million) less than the actual figure. Using the industry cost factors they would have estimated capital expenditures to be 9 percent (or $81 million) less than the actual figure. Total capital expenditures for the 21 plants were $1,152 million during the 1970-1978 period.

III. PULP AND PAPER INDUSTRY

Introduction

Effluent guidelines for the pulp and paper industry were developed for each of 17 subindustrial categories. The guidelines required limitations on pH levels, biological oxygen demand, suspended solids, and zinc in wastewater streams. The major industrial subcategories examined in this analysis are bleached kraft, groundwood, sulfite, soda, de-inked and non-integrated paper segments of the pulp, paper and paperboard industry.

The estimated costs of compliance with BPT regulations, as calculated by both the EPA and the pulp and paper industry, are presented below. These estimates are then compared with the actual water pollution abatement expenditures made by the industry. All of the cost figures in this section are adjusted to 1975 dollars, using the Census Bureau's new plant and equipment price deflator for water pollution abatement equipment.

Methodology and Data Sources

While there are a number of studies which calculate the cost of compliance with BPT in the pulp and paper industry, only three of these are used in this analysis. The reason for this exclusion of data lies in the fact that most of the studies concerning this industry report the estimated expenditures in dollars per ton by subindustry (e.g., bleached kraft; market pulp; papergrade sulfite; soda, de-inked; etc.). In order to compare these cost figures with actual expenditures data, a conversion from dollars per ton to total dollars would have to be made. To make such a conversion, an estimate for the number of treated tons of production in each of these subindustries is needed. Unfortunately, this tonnage figure is not readily available. Therefore, those estimates which are stated only on a dollar per ton basis have been excluded.

The two EPA studies[1] and the one industry study[2] chosen for analysis estimate the industry-wide capital expenditures necessary to meet BPT guidelines on a total dollar basis. These estimates have been adjusted to reflect an 83 percent compliance rate for the industry.[3]

There are four data sources containing information on water pollution abatement capital expenditures in the pulp and paper industry. These include the Census, BEA, and McGraw-Hill publications[4] in addition to a National Council of the Paper Industry for Air and Stream Improvement[5] (NCASI) publication on environmental expenditures in the pulp and paper industry.

---

[1] Economic Analysis of Proposed and Interim Final Effluent Guidelines for the Bleached Kraft, Groundwood, Sulfite, Soda, De-inked and Non-Integrated Paper Sectors of the Pulp and Paper Industry, 1/76, Arthur D. Little, and The Cost of Clean Air and Water Report to Congress, August 1979.

[2] Potential National Economic Impact of Federal Water Effluent Standards and Goals for the U.S. Paper Industry, Arthur D. Little, 12/73, for the American Paper Institute.

[3] Aggregated from compliance data obtained from the EPA Enforcement Office on paper products, paper mills, and pulp mills.

[4] McGraw-Hill Publications Co., Dept. of Economics, Historical Pollution Control Expenditures and Related Data.

[5] NCASI, A Survey of Pulp and Paper Industry Environmental Protection Expenditures - 1978, Special Report No. 79-03, 9/79.

TABLE 5

COST OF SO_2 SCRUBBERS[1] ($/KW)
(1977 Dollars)

	NEW UNIT COST	RETROFIT COST
EXPENDITURE FORECASTS		
EPA - MAY 1976 (Economic and Financial Impacts of Air & Water Pollution Controls on the Electric Utility Industry)	62[2]	79[2]
National Public Hearings on Power Plant Compliance with Sulfur Oxide Air Pollution Regulations (Oct. 1973)	--	71-92
Industry - JUNE 1975 (The Cost of Reducing SO_2 Emissions from Electric Utility Plants)	74	99
ACTUAL EXPENDITURES		
EPA/PEDCO - SEPTEMBER 1978 (Utility FGD Costs: Reported and Adjusted Costs for Operating FGD Systems)	88	103

---

[1] All costs have been adjusted to 1977 dollars using the Chemical Engineering Index to conform with the PEDCO reported data.

[2] Using the inflation rate suggested in the EPA report, the estimated scrubber costs are $65 for a new plant and $82 to retrofit an existing plant.

TABLE 6

THE COST OF COMPLIANCE WITH THE BPT REGULATIONS:
PULP AND PAPER INDUSTRY[1]
(millions of 1975 dollars)

	1974-77	1972-77
Actual Expenditures[2]	\$ 876.0-\$1028.6[3]	\$1411.2-\$1411.9[4]
EPA Estimates		
ADL - Jan. 1976	1304.8	--
Cost of Clean - Aug. 1979	--	1608.2
Industry Estimates		
ADL - Dec. 1973	--	1064.1

---

1. All of the cost estimates below have been adjusted for a compliance rate of 83 percent.

2. These are actual capital expenditures for water pollution abatement by the entire paper and allied products industry.

3. The lower and upper bounds reflect the actual water pollution expenditure data from BEA and McGraw-Hill respectively. The intermediate values are: Census: \$972.2 million and NCASI: \$916.3 million.

4. The upper and lower bounds of this range reflect NCASI and McGraw-Hill expenditures data, respectively.

Cost Comparisons

Tables 6 and 7 depict the estimated capital costs of compliance with BPT relative to the reported actual capital expenditures.

The industry estimate by ADL, approximately 25 percent below the actual 1972-1977 capital expenditures as they are reported by NCASI and McGraw-Hill, is the only estimate of the three which is lower than the reported actual expenditures. It should be noted, however, that the actual data are only available for the entire "Paper and Allied Products" industry, and therefore may overstate slightly the actual expenditures for the pulp and paper segment of the industry.

Both of the EPA estimates are slightly higher than the actual expenditures. The forecasted costs reported in the January 1976 study by ADL averaged 38.1 percent higher than the actual expenditures. The estimate taken from the 1979 Cost of Clean Air and Water report averaged 14 percent higher than the actual expenditures.

TABLE 6

THE COST OF COMPLIANCE WITH THE BPT REGULATIONS:
PULP AND PAPER INDUSTRY[1]
(millions of 1975 dollars)

	1974-77	1972-77
Actual Expenditures[2]	\$ 876.0-\$1028.6[3]	\$1411.2-\$1411.9[4]
EPA Estimates		
ADL - Jan. 1976	1304.8	--
Cost of Clean - Aug. 1979	--	1608.2
Industry Estimates		
ADL - Dec. 1973	--	1064.1

---

1. All of the cost estimates below have been adjusted for a compliance rate of 83 percent.

2. These are actual capital expenditures for water pollution abatement by the entire paper and allied products industry.

3. The lower and upper bounds reflect the actual water pollution expenditure data from BEA and McGraw-Hill respectively. The intermediate values are: Census: \$972.2 million and NCASI: \$916.3 million.

4. The upper and lower bounds of this range reflect NCASI and McGraw-Hill expenditures data, respectively.

TABLE 7

RATIO OF ESTIMATED COST OF COMPLIANCE
TO ACTUAL WATER POLLUTION ABATEMENT EXPENDITURES[1]

	1974-1977	1972-1977
EPA ESTIMATES		
EPA/ADL	1.27-1.49	--
Cost of Clean	--	1.14
INDUSTRY ESTIMATE		
API/ADL	--	.75

---

[1] The range of values reflect comparisons with different expenditure surveys.

IV. PETROLEUM REFINING

Introduction

The BPT effluent guidelines promulgated in October 1974 for the petroleum refining industry require the control of wastewater pollutants for five refinery categories: topping, cracking, petrochemical, lube, and integrated. The effluent guidelines require limitations on pH levels, biological and chemical oxygen demand, suspended solids, oil and grease, phenolic compounds, ammonia, sulfide, and chromium in wastewater streams.

The estimates of the cost of compliance with EPA BPT guidelines and the actual water pollution abatement expenditures made in the petroleum refining industry are presented below. The cost estimates include EPA estimates,[1] industry estimates,[2] and an estimate taken from a study contracted by the National Commission on Water Quality.[3] All of the cost data in this section have been converted to 1974 dollars using the Census Bureau's new plant and equipment price deflator for water pollution abatement equipment.

---

[1] From Economic Impact of EPA's Regulations on the Petroleum Refinery Industry, 4/76, and The Cost of Clean Air and Water Report to Congress, August 1979.

[2] From The Economic Impact of Environmental Regulations on the Petroleum Industry, Phase II Study, Battelle Columbus Laboratories, 6/11/76

[3] From Water Pollution Control Act of 1972. Economic Impacts Pilot Studies, Five Industries, The Conference Board, 6/75.

Methodology and Data Sources

The capital expenditure estimates in the petroleum refining industry are comparable without adjustment. Each estimate includes anticipated expenditures for both existing and new refineries. However, in order to make these estimated capital expenditures consistent with the actual expenditures reported for the petroleum refining industry, all of the estimates were adjusted to reflect an industry compliance level with the BPT guidelines of 83 percent.[1]

There are four sources of actual water pollution abatement expenditures for the petroleum refining industry. These data sources are published by the Bureau of the Census, the Department of Commerce/Bureau of Economic Analysis, McGraw-Hill,[2] and the American Petroleum Institute[3] (API). Unfortunately, only the Census data are broken out for the petroleum refining sector of the petroleum industry.

The API data, while not disaggregated to the level of the individual sectors of the petroleum industry, allocate water pollution abatement capital expenditures to four industrial activities: exploration and production; transportation; marketing; and manufacturing. For the purposes of this study, the manufacturing segment has been chosen as the best approximation for the petroleum refining industry, and it is this portion of the API data which is reported herein.

---

[1] This level of compliance was obtained from the EPA Enforcement Office.

[2] McGraw-Hill Publications Co., Dept. of Economics, Historical Pollution Control Expenditures and Related Data.

[3] API, Environmental Expenditures of the United States Petroleum Industry 1969-1978. Only the data for the manufacturing portion of the industry were employed.

In order to analyze the remaining two sources of actual data at the petroleum refinery level, the ratio of the manufacturing segment expenditures to the total industry expenditures, as reported by API, has been applied to the capital expenditures reported in the BEA and the McGraw-Hill publications.

The Census, API, and McGraw-Hill expenditures data are very similar, while the BEA shows slightly larger capital expenditures for water pollution abatement. These data are shown in Table 8.

Cost Comparisons

As is depicted in Tables 8 and 9, both of the EPA estimates and the industry estimate show substantially greater anticipated expenditures than those that actually occurred. The National Commission estimate is much closer to the reported actual expenditure data. This is largely due to the fact that the National Commission incorporated anticipated technological changes into its model in order to arrive at the minimum estimated cost of compliance with BPT.

A second comparison of EPA and industry estimates is shown in Table 10. This table presents a case study example involving the water pollution abatement expenditures at one petroleum refinery. This example depicts a different trend from that seen previously. Note that both the EPA and the industry estimates are lower than the actual cost of the pollution abatement project, with EPA's estimate 43.8 percent below the actual cost and industry's estimate 26.9 percent lower.

TABLE 8

THE COST OF COMPLIANCE WITH BPT REGULATIONS:
PETROLEUM REFINERY INDUSTRY[1]
(millions of 1974 dollars)

	1974-77	1972-77
Actual Expenditures[2,3]	\$ 545.5-\$ 747.8[4]	\$ 786.8-791.6[5]
EPA Estimates		
Sobotka - April 1976	1397.5	-
Cost of Clean - Aug. 1979	-	1444.4
Industry Estimates		
API/Battelle - June 1976	1426.7	-
National Commission on Water Quality		
Conference Board - June 1975		707.3

---

1. All cost estimates have been adjusted for a compliance rate of 83 percent.

2. Only the API capital expenditures for the manufacturing sector of the petroleum industry are included.

3. The BEA and the McGraw-Hill surveys report data for the entire petroleum industry. In order to obtain an expenditures figure for only the petroleum refinery industry, the API ratio of petroleum manufacturing expenditures to total industry expanditures has been applied to the BEA and McGraw-Hill data.

4. The lower and upper bounds of the range depict the McGraw-Hill and the BEA figures respectively. The intermediate expenditure values are: Census - \$585.8 million and API - \$574.9 million.

5. The lower and upper bounds of the range depict the API and the McGraw-Hill figures respectively.

TABLE 9

RATIO OF ESTIMATED COST OF COMPLIANCE TO ACTUAL WATER POLLUTION ABATEMENT EXPENDITURES[1]

	1974-77	1972-77
EPA Estimates		
Sobotka - April 1976	1.87-2.56	
Cost of Clean - August 1979	-	1.82-1.84
Industry Estimates		
API/Battelle - June 1976	1.91-2.62	
National Commission on Water Quality		
Conference Board - June 1975	-	.89- .90

---

[1] The range of values reflects comparisons with different expenditure surveys.

TABLE 10

CASE STUDY: A WATER POLLUTION ABATEMENT PROJECT

Expenditures by one refinery
(millions of 1972 dollars)

	EPA Cost Estimate	Industry Cost Estimates	Actual Cost
Expenditures	$3.6	$4.683	$6.404
Percent difference from actual	(43.8)	(26.9)	

Source: The Conference Board, Water Pollution Control Act of 1972 Economic Impacts Pilot Studies, Five Industries, 6/75.

V. IRON & STEEL INDUSTRY

Introduction

The BPT effluent guidelines for the integrated iron and steel industry establishes limitations for each individual manufacturing process (e.g., sintering, basic oxygen furnace, etc.). The guidelines require limitations on pH levels, suspended solids, oil and grease, heavy metals, and other pollutants in wastewater streams.

The estimates of the costs of compliance with the BPT regulations and the actual water pollution abatement expenditures in the iron and steel industry are reported below. The estimated costs of compliance which are shown in Table 11 consist of two EPA estimates, one industry estimate, and one estimate from the National Commission on Water Quality. All of the cost figures presented in this section have been converted to 1975 dollars using the Census Bureau's new plant and equipment price deflator for water pollution abatement equipment.

Methodology and Data Sources

In order to compare the cost estimates with actual expenditure data, all the estimates must be adjusted to a common, consistent basis. In the case of the iron and steel industry studies, a number of adjustments to the original estimates were necessary to achieve such consistency. The methodology used in this process is described below.

The first adjustment involved ensuring consistency between the EPA and the industry estimates. The industry estimate, taken from an Arthur D. Little, Inc. (ADL) study conducted for the American

Iron and Steel Institute[1] (AISI), had already been adjusted for comparative purposes in the EPA steel study by Temple, Barker & Sloane (TBS).[2] In an analysis of the capital expenditures necessary to meet BAT guidelines, TBS achieved comparability with the ADL estimates by applying a .9652 factor to the ADL cost figures. This same factor was applied to the ADL estimate used in this analysis for the capital expenditures needed to meet the BPT guidelines.

The second adjustment concerned accounting for Construction Work in Progress (CWIP) in the cost estimate. It was necessary to adjust the cost estimates for the inclusion of CWIP since the reported actual capital expenditures include this cost element. While the TBS study includes a CWIP figure, the ADL report does not. Since the TBS and ADL figures were already on a comparable basis, the TBS reported CWIP was added to the adjusted ADL estimate. This procedure yielded an industry estimate which was inclusive of CWIP. Finally, all of the cost estimates were weighted by a compliance factor of 54 percent.[3]

There are four sources which report capital expenditures for water pollution abatement in the iron and steel industry. These are: the Bureau of the Census Current Industrial Reports,[4] (Census), the Department of Commerce/Bureau of Economic Analysis[5]

---

[1] ADL, Steel and the Environment: A Cost Impact Analysis, 5/75.

[2] TBS, Economic Analysis of Proposed and Interim Final Effluent Guidelines, Integrated Iron and Steel Industry, 3/76.

[3] This is the compliance rate for the Iron and Steel Industry as reported by the EPA's Enforcement Office.

[4] Pollution Abatement Cost and Expenditures, annual sin-e 1973.

[5] Articles on pollution abatement and control expenditures are published in the June and February issues of the Survey of Current Business.

(BEA), the American Iron and Steel Institute[1] (AISI), and McGraw-Hill.[2]

The iron and steel industry capital expenditures are reported separately in each of these sources except for the BEA publication. The related industries for which expenditures are reported by the BEA are "primary metals", "blast furnaces and steel products", and "non-ferrous metals". In order to capture the amount expended by steel and iron foundries, as well as that expended by "blast furnaces and steel products", the expenditures by the non-ferrous metals industry were removed from total "primary metals" expenditures. The resulting figures are the BEA capital expenditures included in this analysis.

The data from the four sources differ somewhat and the range of actual capital expenditures is depicted in Table 11. Each cost estimate is examined relative to the reported actual expenditures in Table 12.

Cost Comparisons

As is shown in Table 12, all of the earlier estimates of the cost of compliance with BPT were significantly higher than the actual expenditures reported by the four sources of actual pollution control costs. The AISI/ADL industry estimate is particularly high. This estimate of $1,613.5 million is 247% higher than the AISI actual water pollution abatement expenditure figure.

The best estimate of the cost of compliance with the BPT guidelines was made by EPA in the 1979 Cost of Clean Air and Water. This estimate of $593.7 million for the years 1972 1977 is 15.2% lower than the AISI actual expenditure figure.

---

[1] AISI Statistical Highlights U.S. Iron and Steel Industry 1969-1978.

[2] McGraw-Hill Publications Co., Department of Economics, Historical Pollution Control Expenditures and Related Data.

TABLE 11

COSTS OF COMPLIANCE WITH BPT REGULATIONS: THE IRON AND STEEL INDUSTRY[1]
(millions of 1975 dollars)

	1975-77	1973-77	1972-77
Actual Expenditures[2]	465.1-630.0[3]	624.3-952.6[4,5]	699.9-1070.6[5,6]
EPA Estimates			
TBS - March 1976	831.6[7]	-	-
Cost of Clean - Aug. 1979	-	-	593.7
Industry Estimates			
AISI/ADL - May 1975	1613.5	-	-
National Council on Water Quality Estimate, The Conference Board[8] - June 1975	-	1173.6	-

---

1. These costs reflect the capital expenditures only.

2. The BEA figure represents the pollution abatement expenditures by the primary metals industry less those expenditures made by the non-ferrous metals industry.

3. This range is bounded on the lower end by the AISI expenditures figure and by the McGraw-Hill cost figure in the upper end. The intermediate Census and BEA figures are $513.4 and $479.7 million respectively.

4. The lower bound of the range reflects the AISI cost figure and the upper bound reflects the McGraw-Hill cost figure. The intermediate Census and BEA figures are 714.8 and 645.0 respectively.

5. The Census data for 1973 are not broken out by air and water. To obtain only the capital expenditures for water pollution abatement, the 1973 total expenditure figure was adjusted using the 1974 ratio of water control expenditures.

6. The lower bound of the range is the AISI cost figure and the upper bound is the McGraw-Hill cost figure.

7. This is the cost estimate reported by TBS as the capital expenditure required to meet BPT. Since TBS did not feel that compliance with the BPT guidelines could be met in 1977, this estimate differs from the TBS estimate of expenditures for the years 1975-1977. The BPT estimate was chosen since it is more comparable to the other estimates studied.

8. The Conference Board, Water Pollution Control Act of 1972 Economic Impacts Pilot Studies, Five Industries, 1975.

TABLE 12

RATIO OF ESTIMATED COST OF COMPLIANCE TO ACTUAL WATER POLLUTION ABATEMENT EXPENDITURES[1]

	1975-1977	1973-1977	1972-1977
EPA Estimates			
TBS - March 1976	1.32-1.79	-	-
Cost of Clean - Aug. 1979	-	-	.55-.85
Industry Estimate			
AISI/ADL - May 1975	2.56-3.47	-	-
National Commission on Water Quality			
The Conference Board - June 1975	-	1.23-1.88	-

---

[1] The ranges of values reflect comparisons with different expenditure data surveys.

VI. AUTOMOBILES

Introduction

The 1970 Amendments to the Clean Air Act called for EPA to establish emission standards for 1975 and later model year light duty passenger cars to require a 90 percent reduction in hydrocarbon (HC) and carbon monoxide (CO) emissions from 1970 levels, and to proscribe standards for 1976 and later model years to require a 90 percent reduction in nitrogen oxide (NO_x) emissions from 1971 levels. A number of controversial suspension hearings, judicial reviews and legislative changes have altered the original emission standards and extended their compliance dates. Consequently, many of the earlier cost studies were for emission standards that were never placed in effect or were delayed several years from their original timetable.

Methodology and Data Sources

The methodology for this analysis was straightforward. It consisted of collecting the data and adjusting the sticker price increases to constant dollars. Estimates of sticker price increases are provided by EPA, the National Academy of Sciences, automobile manufacturers as reported in EPA automobile emission control status reports, and by the Council on Environmental Quality. Actual price increases are taken from two sources: the Bureau of Labor Statistics and manufacturers' reported actual price increases submitted in letters to Senators E.S. Muskie and P.V. Domenici.

Cost Comparisons

Table 13 compares actual and estimated sticker price increases due to emission controls. Table 14 lists the ratio of estimated price increases to actual price increases for model years 1973-1974, 1975-1976, and 1980. For the 1973-1974 standard the EPA and CEQ estimates appear to be the best, however, both estimates are substantially higher than reported price increases. For the 1975-1976 standard the EPA and NAS estimates appear to give the closest results to the reported figures. The manufacturers' estimates show a considerable amount of variance. This is not unexpected since there are significant differences in economies of scale between large and small manufacturer Individual manufacturer estimates were not indicated in these ranges. In comparing EPA estimates for the 1980 model year with the b[illegible] data we find that EPA has underestimated the control costs by 18 percent. This is in contrast to the 1973-1974 standard where EPA overestimated the cost by 32-69 percent.

From analyzing the data in Table 13 and Table 14, it appears that the EPA estimates are closer to the actual price increases than the manufacturer estimates. The manufacturers' estimates have a large degree of variance and since individual manufacturer estimates are not given it is impossible to determine if they consistently overestimate control costs without knowing if the higher estimates are from the larger manufacturers.

As many of the early estimates were for standards that were never implemented, comparisons with actual data are not possible. However, Table 15 lists various estimates for meeting these standards. It should be noted that comparing the (.41/3.4/2.0)[1] standard with model year 1977, provides cost estimates of applying control equipment to reduce HC and CO emissions from the 1977 level of 1.5 g/mi for HC and 15 g/mi for CO. Comparing the (.41/3.4/.4) standard with model year 1977 reflects the cost of the above reductions plus lowering NO_x emissions from 2.0 g/mi to .4 g/mi. In comparing the (.41/3.4/.4) standard with an unregulated vehicle all the estimates tend to group together except the EPA estimate which is low. For the other (.41/3.4/.4) standard there appears to be no clear-cut trend. For the (.41/3.4/2.0) standard the DOT/EPA/FEA estimates are significantly lower than the manufacturers' estimates.

---

[1] The first number in the parentheses refers to the HC emission standard, the second figure refers to the CO emission standard, and the last number refers to the NO_x standard. All standards are given in units of grams per mile.

TABLE 13

COMPARISONS OF ESTIMATED AND ACTUAL STICKER PRICE INCREASES DUE TO EMISSION CONTROLS
(1977 Dollars)

Emission Standards	Bureau of Labor Statistics Actual Price Increases[1,2]		Manufacturers Reported Actual Price Increases[3]		EPA Estimates[4]		NAS Estimates[6]		Manufacturer Estimates[7]		CEQ Estimates[9]	
(HC/CO/NO_x)	Incremental	Cumulative	Incremental	Cumulative	Incremental	Cumulative	Incremental	Cumulative	Incremental	Cumulative	Incremental	Cumulative
MY 70-71 (4.1/34/--)	33	33	27	27	39.00		28		--	--	35	35
MY 72 (3.0/28/--)	8	41	19	41		39.00		28	--	--	2	37
MY 73-74 (3.0/28/3.1)	35	76	24	65	61.00	100-110[5]	93	121	55-132	55-132	61	98
MY 75-76 (1.5/15/3.1)	139	215	144	209	100-110	200-220	83	204	55-364	110-496	209	307
MY 77-79 (1.5/15/2.0)	35	250	--	--	15	215			0-182[8]			
MY 80 (.41/7.0/2.0)	99	349	--	--	70	285			--			
MY 81 (.41/3.4/1.0)	--	--	--	--	150	435			154-378[8] (over MY 75-76)			

---

[1] These figures are from the Bureau of Labor Statistics reports on price changes of new passenger cars. Price increases were adjusted to 1977 dollars.

[2] Incremental prices are the prices over the previous model year. Cumulative prices are the prices over pre-1970 cars.

[3] These prices are sales weighted averages of GM, Ford, and Chrysler average price increases due to emission controls as reported by Mr. E. M. Estes, President, General Motors, to Senator E. S. Muskie, May 19, 1975; Mr. L. A. Iacocca, President, Ford Motor Co., to Senator P.V. Domenici, May 13, 1975, and Mr. J. J. Ricardo, President, Chrysler Corp., to Senator P.V. Domenici, May 21, 1975.

[4] For the 1970-1974 model years the EPA figures reflect estimates in The Economics of Clean Air, Annual Report to Congress, March 1972 and the Cost of Clear Air and Water Report to Congress, August 1979. Other estimates are from the EPA Fact Sheet #1, 1978 and an EPA report entitled Automobile Emission Control - The Technical Status and Outlook as of December 1974.

[5] The upper bound cumulative cost reflect EPA estimates taken from the December 1974 status report. It did not give incremental costs for previous model years.

[6] The estimates for model years 1970-1972 were taken from the NAS 1972 report (Semiannual Report by the Committee on Motor Vehicle Emissions). The 1974 NAS report provided the estimates for the 1974 and 1975 model years.

[7] The manufacturing estimates are reported in the December 1974 EPA status report on automobile emission controls cited above and in a similar status report dated April 1976.

[8] The costs were only expressed as an increment over the prior model year in the April 1976 EPA Status Report.

[9] These estimates are from the Economic Impact of Pollution Control, March 1972.

TABLE 14

RATIO OF ESTIMATED TO ACTUAL STICKER PRICE INCREASES[1, 2]

Emission Standards ($HC/CO/NO_x$)	Actual Price Increases	
	BLS Data	Manufacturers' Data
MY 1973-1974 (3.0/28/3.1)		
EPA Estimate	1.32-1.45	1.54-1.69
NAS Estimate	1.59	1.86
Manufacturer Estimates	.72-1.74	.85-2.03
CEQ Estimate	1.29	1.51
MY 1975-1976 (1.5/15/3.1)		
EPA Estimate	.93-1.02	.95-1.05
NAS Estimate	.95	.97
Manufacturer Estimates	.51-2.31	.53-2.37
CEQ Estimate	1.42	1.47
MY 1980 (.41/7.0/2.0)		
EPA Estimate	.82	

---

[1] All comparisons are with cumulative estimates.

[2] The range of values reflects comparisons of the various estimates of sticker price increases with the actual reported increases.

TABLE 15

COMPARISON OF ESTIMATED STICKER PRICE INCREASES DUE TO PROPOSED EMISSION STANDARDS
(1977 Dollars)

Emission Standard ($HC/CO/NO_x$)	Base Year[1]	EPA[2,3]	DOT/EPA/FEA[4]	CEQ[5]	NAS[6]	GM[7,8]	FORD[8]	Chrysler[8]	Industry Average
(.41/3.4/.4)	Uncontrolled	291-496		442	378-498	402-549	--	--	--
(.41/3.4/.4)	MY 77	--	250-340	--	-	165-375	316-401	127-287	204-368
(.41/3.4/2.0)	MY 77	110-165	35-125	--	--	149	165	237	184

---

[1] Costs are expressed as an increment above the base year.

[2] For the (.41/3.4/.4) standard the lower estimate was given in the March 1976 status report Automobile Emission Control - Current Status and Development Trends, the higher estimate was given in the December 1974 status report. The Economics of Clean Air Report to Congress, 1972 gives an intermediate estimate of $418.

[3] For the (.41/3.4/2.0) standard the values are reported in the hearings transcript for the Suspension of the 1977 Standards.

[4] An Analysis of Alternative Motor Vehicle Emission Standards, May 19, 1977, prepared by DOT/EPA/FEA for use in Congressional debates on the Clean Air Act Amendments of 1977.

[5] The Economic Impact of Pollution Control, March 1972.

[6] The lower value is from the 1972 Semiannual Report by the Committee on Motor Vehicle Emissions and the higher value is from the 1974 Committee report.

[7] The estimated range for the (.41/3.4/.4) standard is from the Application for Suspension of the 1975 Standards submitted to EPA on December 22, 1972.

[8] The auto company estimates are in the Suspension transcript or Applications for Suspension of the 1977 Standards.

By EDWARD F. DENISON

Pollution Abatement Programs: Estimates of Their Effect Upon Output Per Unit of Input, 1975-78

CONTROLS imposed to protect the physical environment against pollution have reduced the growth rate of measured output per unit of output in nonresidential business. Estimates of the effect of these controls for 1967–75 were contained in "Effects of Selected Changes in the Institutional and Human Environment Upon Output Per Unit of Input," by Edward F. Denison, in the January 1978 SURVEY OF CURRENT BUSINESS. The estimates are extended here to 1978.[1] The January 1978 article describes the concepts underlying the estimates, including the distinction between costs of pollution abatement that curtail output per unit of input and those that do not. It also explains that the purpose of the estimates "is to aid analysis of growth and productivity; it is not to judge the wisdom of Government programs, which have benefits as well as costs."

The 1975–78 estimates show that increasing costs of environmental protection continued to cut into the growth rate of output per unit of input. But the most interesting finding is that the size of the deduction from the annual growth rate, which had climbed to 0.22 percentage points in 1973–75, fell back to 0.08 percentage points in 1975–78.

Table 1 shows the dollar value of incremental pollution abatement costs of types that reduce output per unit of input in nonresidential business. Incremental costs refer to the excess of total costs over the costs that would have been incurred if the 1967 level of abatement costs had continued unchanged except as a result of output growth and price level changes. The estimates incorporate changes made in underlying data since the original 1967–75 series were prepared. The resulting revisions were trivial for the total incremental cost of pollution abatement and its effect on output per unit of input. Some individual cost components changed considerably, but changes were offsetting.

Incremental costs of pollution abatement had risen from nothing (by definition) in 1967 to $9.3 billion in 1975. They reached $16.3 billion in 1978. Nearly one-half of the total consists of current costs. The rest is depreciation on capital required for pollution abatement and the net opportunity cost of devoting capital to this purpose. By 1975, changes in environmental controls introduced since 1967 had diverted nearly 1 percent of the labor, capital, and land used in nonresidential business from production of measured output to pollution abatement activities that do not result in measured output (table 2, column 1). By 1978 this percentage had risen to almost 1.2, leaving 98.8 percent of total input available for other uses (table 2, column 2). This implies that in 1978 output per unit of input was 98.8 percent as large as it would have been if environmental protection had been as it was in 1967. These percentages are converted to index form in table 2, column 3. The index traces the course that measured output per unit of input in nonresidential business would have followed if nothing had changed except pollution abatement.

The growth rate of this index in any period measures the contribution to—in this case, amount that was deducted from—the growth rate of output per unit of input by diversion of resources to pollution abatement. Index growth rates for selected periods follow:

	Contribution to growth rate
Before 1967	0
1967–69	−.05
1969–73	−.10
1973–75	−.22
1975–78	−.08

The deduction was smaller in 1975–78 than in 1973–75 simply because the percentage of labor and capital devoted to pollution abatement was not rising as fast.

The growth rate of output per unit of input from 1948 to 1973 was slightly under 2.0 percent, according to one calculation.[2] The rising cost of pollution abatement would have cut 0.22 percentage points from that rate in 1973–75, an amount equal to one-ninth of that rate. After 1975 the adverse effect was much smaller, 0.08 percentage points. Pollution abatement was, of course, only one cause of the large drop in the growth rate of output per unit of input after 1973.

---

[1] Estimates in the January 1978 article for effects of increased requirements to protect safety and health and for effects of a rise in dishonesty and crime have not been extended.

NOTE.—The estimates were prepared under the author's supervision by James Embersit and Bruce Baker of BEA's Environmental and Nonmarket Economics Division.

[2] Edward F. Denison, "Explanations of Declining Productivity Growth," SURVEY OF CURRENT BUSINESS August 1979, Part II, table 1.

Table 1.—Incremental Pollution Abatement Costs That Reduce National Income Per Unit of Input in Nonresidential Business

[Millions of dollars]

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978 [1]
Current costs:												
1. Motor vehicle emission abatement [2]	0	71	147	210	325	457	641	1,064	1,380	1,591	1,808	....
2. Air and water pollution abatement except motor vehicle emissions	0	53	152	370	621	914	1,239	1,939	2,528	3,074	3,670	....
a) Direct labor cost	0	18	52	126	211	311	421	599	733	855	951	....
b) Equipment leasing, materials, supplies, services and other	0	35	100	244	410	603	818	1,340	1,795	2,219	2,719	....
3. Payments to use public sewer systems	0	22	43	65	108	151	194	210	233	293	372	....
4. Solid waste disposal	0	22	49	75	110	145	197	257	321	423	542	....
Depreciation:												
5. Motor vehicle emission abatement [2]	0	4	10	17	29	44	67	104	163	239	329	....
6. Air and water pollution abatement except motor vehicle emissions	0	24	60	140	272	401	583	913	1,347	1,639	1,971	....
7. Solid waste disposal	0	1	2	5	9	15	24	38	53	67	84	....
Net opportunity costs of invested capital:												
8. Motor vehicle emission abatement [2]	0	4	10	18	25	37	55	83	126	177	234	....
9. Air and water pollution abatement except motor vehicle emissions	0	67	189	454	734	1,109	1,572	2,337	3,374	3,989	4,733	....
10. Solid waste disposal	0	1	3	7	13	21	34	51	70	81	99	....
Less:												
11. Value of energy and materials reclaimed	0	8	17	27	48	74	93	136	267	407	421	....
Total incremental cost	0	261	667	1,332	2,218	3,220	4,513	6,860	9,328	11,146	13,421	16,300

1. Based on preliminary estimates. Detail not available.
2. Business vehicles only.

NOTE.—The estimates for 1968–71 were prepared by the same methods used for the 1968–71 estimates in the January 1978 SURVEY article referred to in the text; for 1972–77, by the same methods used for the 1972–74 estimates in that article; and the preliminary estimates for 1978, by the same methods used for the 1975 estimates in that article. BEA's series on total expenditures for, and capital expenditures for, pollution abatement and control, the main data underlying these estimates, appeared in the February and June 1979 issues of the SURVEY, respectively.

Table 2.—Pollution Abatement Costs: Effect Upon Output Per Unit of Input in Nonresidential Business

	Percentage of total input diverted to pollution abatement	Percentage of total input not diverted to pollution abatement	Effect of pollution abatement costs upon output per unit of input	
			Index 1972 = 100	Percent change in index
	(1)	(2)	(3)	(4)
1967	0	100.000	100.42	....
1968	.044	99.956	100.37	−0.04
1969	.103	99.897	100.31	−.06
1970	.204	99.796	100.21	−.10
1971	.318	99.682	100.10	−.11
1972	.416	99.584	100.00	−.10
1973	.518	99.482	99.90	−.10
1974	.742	99.258	99.67	−.23
1975	.984	99.052	99.47	−.21
1976	1.006	98.994	99.41	−.06
1977	1.083	98.917	99.33	−.08
1978	1.182	98.818	99.23	−.10

NOTE.—Columns 1 to 3 are equivalent to columns 8 to 10 of table 4, p. 31, in the January 1978 SURVEY, except that columns 1 and 2 are expressed as percentages instead of ratios. See also note to table 1.

The Economic Effects of the Clean Air Act

by Robert M. Wolcott and Adam Z. Rose

Prepared for the
Natural Resources Defense Council
Washington, DC

by

Public Interest Economics Foundation
1525 New Hampshire Avenue, N.W.
Washington, DC 20036

March 1982

Executive Summary

The aggregate impacts of the Clean Air Act on the U.S. economy are extremely small and, on balance, positive. Conventional measures of the health of the economy (such as gross national product, unemployment, prices, and labor productivity) show very small gains or losses due to the Clean Air Act. Moreover, when these measures are adjusted to take into account health, environmental, and economic impacts that are not reflected in conventional market transactions, the economic effects of the Clean Air Act are shown to be clearly beneficial.

Our review and synthesis of the literature yield the following conclusions regarding the Act's impact to date:

- Output has remained essentially unchanged, with only a modest reduction of approximately 0.1 percent per year. When adjusted to take into account benefits not reflected in market transactions (such as the value of improved health), real welfare has increased.
- Unemployment was 0.1 to 0.2 percent lower per year than it would have been without clean air legislation.
- Prices (measured by the Consumer Price Index) increased very slightly, from 0.1 to 0.2 percent per year. Consideration of benefits not reflected in market transactions suggests that air pollution controls have had virtually no effect on inflation.
- Relaxing air quality requirements enough to reduce capital costs for air pollution control by 30 percent would change output, prices, and employment imperceptibly, by less than 0.1 percent for each indicator.

- Labor productivity, as conventionally measured, has been essentially unaffected, with a reduction of less than one percent per year reported by the most adverse studies. Recent work incorporating the Act's non-market benefits into conventional measures of output, suggests that the Act has increased labor productivity.

- The Clean Air Act's benefits substantially exceed compliance costs. The most comprehensive survey to date estimates benefits of $21.4 billion, and costs of $17.0 billion.

- Compliance expenditures by the private sector have remained stable in real terms since 1975 -- on average, less than 3 percent of gross private domestic investment. Total expenditures by business, consumers and government were 0.6 percent of GNP for the 1972-1979 period.

- Abatement costs could be reduced further by continued use of emission offsets and other market-based "controlled trading" mechanisms.

The evidence will not support charges that the Clean Air Act is imposing severe costs on the U.S. economy. Net benefits have resulted, and macroeconomic measures have remained essentially unchanged. The Clean Air Act is, on balance, sound environmental policy and is consistent with sound economic policy.

I. Introduction

The Clean Air Act establishes national air quality objectives and programs for achieving them. In 1970 and again in 1977, Congress sought to safeguard the health and welfare of all groups within society, including the young, the old, persons with respiratory disease, and other sensitive groups -- composing approximately 20 percent of the national population.

The Clean Air Act and its related programs are frequently charged with imposing excessive economic costs on the U.S. economy. Fair scrutiny of the Clean Air Act's reported economic impacts fails, however, to support such an assertion. In fact, the Clean Air Act has had a very minor impact on the aggregate economy and, in many instances, a positive one at that.

In this paper we present a synthesis of the published results to date on the macroeconomic impacts of the Clean Air Act. We present the range of estimates obtained for effects on economic growth, inflation, unemployment, and labor productivity. From these we distill our best estimates of the macroeconomic impacts of the Act and its related regulations.

II. The Impacts of the Clean Air Act on Economic Output, Prices, and Employment

Assessing the net consequences of the Clean Air Act on the output and growth of the U.S. economy, on price stability, and on employment levels is a highly complex task. A comprehensive assessment must reach beyond a mere summation of firm- and industry-specific impacts. The American economy is highly interdependent. The actions of individual business enterprises affect other firms and consumers through the workings of markets for goods, inputs to production (such as labor, capital, and materials), and money. The pollution control measures undertaken by each firm are likely to have benefits for other enterprises and individuals which are not reflected in conventional economic measures of market transactions. Many "indirect" or "second-order" effects must be evaluated. Some of these are:

- Increased demand for pollution control causes an increase in demand for machinery, materials, and labor, thus increasing sales and employment elsewhere in the economy;
- Increased income generated by activity in the pollution control industry generates additional demand for consumer goods;
- Higher costs of production in some firms due to pollution control requirements are passed on to other firms and to consumers, thus reducing purchasing power and consumption;
- Reductions in air pollution improve the well-being of individuals and the productivity of other firms and economic sectors.

Macroeconomic models of the economy can be used to estimate the effects of pollution control costs on the general economy, taking both first and second-order consequences of such expenditures into account. Such estimates, however, are only as good as the basic cost data fed into them, and the assumptions on which the models are constructed.

The following sections examine selected compliance cost data, and certain key analytic assumptions of the models themselves. We then review and synthesize the studies performed to date.

A. Abatement Expenditures: Composition and Trends

Estimates of the macroeconomic impact of the Clean Air Act are based in the first instance on estimates of the costs of complying with the Act's requirements. There are estimates of both investment and annual costs. Four principal sources of national pollution control cost data are available to researchers:

1. Estimates of incremental costs attributable to federal environmental regulations by the U.S. Environmental Protection Agency;
2. Estimates of total pollution control outlays, by the Bureau of Economic Analysis of the U.S. Department of Commerce;
3. Estimates of industrial (manufacturing) capital cost for pollution control, by the U.S. Bureau of the Census; and
4. Estimates of the percent of future capital investment which is expected to go to pollution abatement, by McGraw-Hill.

The Bureau of Economic Analysis data is generally considered the most consistent and accurate source of historical data for combined capital and annual costs. The Bureau of the Census estimate, because of its very extensive data base, is the most precise, but it is available only for manufacturing sectors of the economy. The McGraw-Hill data is available only in percentage terms and excludes operating and maintenance costs. Hence, it is not useful in macroeconomic assessment efforts.

The EPA estimates are the only cost data available in incremental form. In addition, they include estimates of future costs as well as past and present expenditures. For these reasons the EPA data has been used in each of the national macroeconomic assessments presented below. However, evidence suggests that the EPA data consistently overstate costs, because the assumption is made that all sectors comply fully with regulations, and that no economies of scale or savings from process changes are realized by industry. For this reason, the national macroeconomic impacts discussed below are somewhat overstated.

Because the BEA estimates appear to be the most consistent and accurate, we discuss them further below.

According to the BEA, air pollution control expenditures have been substantial in absolute terms, but small in relation to total investment and consumption in the entire U.S. economy. A large fraction of the costs have been borne by a small number of industries which emit a large fraction of U.S. air pollution.[1/] Most other economic sectors, however, have been virtually unaffected.

Between 1972 and 1979, total air pollution abatement expenditures, including capital, operating and maintenance costs, were $65.2 billion (in constant 1972 dollars).[2] This level of expenditures is modest in contrast to both total investment and GNP in the U.S. economy. Gross private domestic investment, for example, totalled $1.62 trillion (in 1972 dollars) in the 1972-79 period.[3] Private industry expenditures for air pollution controls -- including both capital and operating and maintenance costs -- amounted to 2.7 percent of this total. The total expenditures on air pollution abatement represent 0.6 percent of total GNP for the same period.

Consumer and government expenditures remained essentially flat between 1976 and 1979. Business expenditures rose very modestly. (See Table 1) The data reflect an initial surge of spending in the first years of the clean air program, which leveled off in the 1976 to 1979 period. Factors that may be related to this leveling include increased efficiency in the installation and operation of abatement equipment, a decline in the number of existing sources installing pollution controls for the first time, and a general economic slowdown which reduced construction of new and substantially rebuilt facilities.

Even the BEA data presented here may substantially overstate the true costs of complying with the Clean Air Act. The BEA collects this data through an annual survey, asking

Table I

Air Pollution Abatement Expenditures

(in millions of constant 1972 dollars)

	1972	1973	1974	1975	1976	1977	1978	1979
Business	4165	4990	5057	5768	5840	5818	6054	6315
Capital Account	2553	3143	3156	3610	3443	3331	3330	3445
Current Account	1632	1847	1901	2158	2397	2487	2724	2870
Government	142	123	130	137	176	188	166	180
Consumers	1536	1965	2117	2588	2934	2944	2990	2990
Total	5843	7078	7304	8493	8872	8950	9210	9485

Source: Rutledge, Gary L., and Trevathan, Susan L. "Pollution Abatement and Control Expenditure," *Survey of Current Business*, March 1981, Volume 61, Number 3, p. 19.

firms to report their compliance expenditures. Surveys of this kind tend, however, to exaggerate pollution control costs. The reason is that many pollution control measures are actually process changes that improve productivity, by conserving energy or recapturing useful materials, or otherwise increasing the yield of factor inputs. Firms should allocate part of the cost of such changes to conventional investment in modernization or expansion. Many, however, attribute the entire cost of such changes to complying with air pollution regulations.

In addition, industries historically have tended to overestimate the costs of controlling pollution. A recent retrospective study of cost estimates in six major industries showed that in the majority of cases, both industry and EPA overestimated the cost of complying with environmental standards.[4/]

Even where estimates accurately reflect a private firm's expenditures for pollution controls, estimates of private pollution control costs may overstate the net social outlay for those controls. Simply put, some of the outlays of a firm to meet air quality regulations are merely transfer payments to other firms within the overall economy and do not represent real resource or social costs. Only real resource costs are relevant in assessing the true impacts of regulation on economic welfare.

B. Key Assumptions and Considerations in Evaluating the Macroeconomic Studies

Macroeconomic estimates of the net effects of the Clean Air Act on the economy are premised on certain key assumptions as to how firms, sectors, and individuals respond to the regulation-related changes. We discuss below several key assumptions which bear on the interpretation of particular studies.

1. Investment Displacement

Investment is the principal "supply-side" determinant of the level of economic activity. The effect of pollution abatement requirements on total investment is disputed among economists. Specifically, the debate relates to whether pollution control investments supplement ordinary investment, or whether they displace or "crowd out" such investment.[5] If such investments supplement ordinary investment, then pollution control programs provide an expansionary impetus to the economy. On the other hand, if such investments displace ordinary investment, pollution control programs result in economic contraction.

Pollution control investment could fully displace conventional investment only if the supply of capital were fixed. Obviously, however, greater demand for capital induced by pollution control requirements raises the interest rate that capital can command. This, in turn, draws more capital into the market. Some displacement can occur, because some conventional investments that would have been made at the prior interest rate now will not be made at the higher rate. But the total investment made will be greater than before.[6] The relevant question, therefore, is by how much does pollution control investment supplement conventional investment.

Most empirical studies of specific industries indicate that pollution control investment is primarily supplementary, not displacing. Based on such findings, Data Resources, Inc. (DRI) estimates in its macroeconomic studies (discussed below) that $1.00 invested in pollution control displaces only 33-40¢ of investment in other plant and equipment, resulting in a net stimulus of 60-67¢.[7]

Especially when an economy is in a relatively slack period with slow output growth and excess industrial capacity, it is unreasonable to assume that all capital diverted by pollution abatement could have been absorbed in conventional investment at sustained yields and productivity rates. The years 1970 to 1979 were such a period for the U.S. economy. Average industrial capital utilization in the 1970-1979 period was 81.7 percent, as opposed to 84.9 percent from 1960 to 1969.[8] It is highly improbable that conventional investment could have absorbed the amount of expenditures on pollution abatement investment without a drop in the yield which capital generated in this period. Thus, pollution abatement expenditures may have increased the overall demand for capital (and also output, employment, and income) beyond levels which would have existed in the absence of regulation.

Our judgment is that pollution abatement investment is, to a substantial degree, supplementary to conventional investment and that the DRI percentage allocation is a reasonable estimate of the degree to which these investments are supplementary.

2. Incidence of Costs

The degree to which producers are able to pass on cost increases to consumers and suppliers of the factors of production affects the degree to which output, prices, and employment change with pollution abatement investment.

Markets in which many substitutes are available constrain the ability of firms to pass costs through to their consumers. In contrast, when few substitutes are available, increased costs can be readily passed through.[9] The domestic steel industry, for example, has a limited ability to pass costs through to consumers due to foreign competition. The electric utility industry, in contrast, can pass a much greater portion of such costs through to consumers due to its natural monopoly status.

Full pass-through of pollution control expenditures, however, is as unlikely to occur as full displacement of investment. Some of the macroeconomic studies, however, make this assumption, leading to exaggerated projections of impact on output and prices. The results of these studies must be interpreted with this caveat in mind.

3. Effects Not Reflected in Conventional Economic Indicators

Conventional macroeconomic analyses are restricted to measuring effects which are registered in conventional economic markets. The failure to take into account non-market benefits and costs substantially biases the results of such studies against environmental regulations. Efforts are being made to incorporate non-market effects into the modeling techniques.[10/] But until such efforts come to fruition, results of conventional analyses must be viewed as tending to exaggerate the adverse economic effects of such regulations.

C. The Impacts of Pollution Control Costs: Results of Recent Macroeconomic Studies

Macroeconomic studies of the effects of pollution controls have focused on three principal measures: the aggregate level of production, the amount of total employment and the degree of price stability.

There are two major indicators of production. The first is Gross National Product (GNP), the value of final goods and services produced in a given year. The second is Gross Output, which includes final goods and intermediate goods. Typically, these two indicators move in the same direction, i.e., an increase in one usually means an increase in the other. It has been suggested, however, that an increase in air pollution control regulations raises the amount of intermediate production needed to deliver a constant level of demand for final goods or GNP. However, this argument only counts measured GNP. If the improvements in the quality of life were factored in, the positive correlation between changes in Gross Output and GNP would hold. Most of the studies we examined use Gross Output as their measure of production, but the results are applicable to GNP as well.

Unemployment is used as a proxy for the efficiency at which an economy operates. An economy cannot be working at its full potential if resources are idle. Barring major changes in the labor force participation rate, unemployment and employment move in opposite directions. Most of the studies evaluated below measure employment, but the results are readily transferable to measuring unemployment changes.

Price stability or the lack of it, inflation, measures the degree to which wealth and purchasing power are maintained. Most of the studies examined make use of the Consumer Price Index. There are various other price indices, but all typically move together, though sometimes with a short lag.

Eight studies of the aggregate impact of pollution control regulations on the U.S. economy, or on various regions, are summarized in Table 2. Most focus on air pollution controls alone; several study air and water pollution controls combined. The studies differ somewhat in terms of the time period and geographic location observed, regulations involved, and indicators measured. All of them, however, suggest that economic impacts are minor, and most show the impacts to be negligible.

1. National Studies

The first four studies listed in Table 2 are nationwide in scope. Nearly all the results suggest effects of less than one-half of one percent in either direction on any measure of economic performance.

The most comprehensive studies to date are those by DRI (1979, 1981). These studies considered both air and water pollution control requirements, in the aggregate, between 1970 and 1987 (1988 for the most recent study, i.e. 1981). In both studies output effects are positive in the early stages of the study period due to the investment stimulus of pollution control. However, by 1981, as productivity, conventionally measured, decreases and cumulative operating and maintenance expenses take hold, output falls ever so slightly. Employment is expanded throughout the period and consumer prices maintain a very gradual rate of increase

The results of the 1979 DRI study are biased slightly in a positive direction due to the assumption that real government spending is unaltered by inflation. On the average, the study projects GNP to decline by 0.1 per year, unemployment to fall by 0.2-0.3 percent per year, and prices to increase approximately 0.2 percent per year.

DRI's revised 1981 projections are very similar to those made in 1979. The differences are due primarily to: (1) increased sensitivity of comsumer prices to changes in

Table 2: Summary of Findings

Study	Area Period	Regulations Covered	Impacts (percentage change)[a/]			Study Bias [d/]
			Output[b/]	Employment	Inflation[c/]	
Chase (1975)	U.S./ 1974-82	Clean Air Act, Clean Water Act/ Stationary Sources	-1.59 to +1.51[e/]	-.42 to +.39	n.e.	High investment displacement assumption; high price mark-ups
DRI (1979)	U.S./ 1970-86	Clean Air Act, Clean Water Act/ Stationary Sources	-.89 to +.60[e/]	+.17 to +.47	+.11 to +.50	No displacement from government spending
DRI (1981)	U.S./ 1970-87	Clean Air Act, Clean Water Act/ Stationary Sources	-.31 to +.24[e/]	+.10 to +.41	+.12 to +.76	No displacement from government spending; full price mark-ups
Hollenbeck (1979)	U.S./ 1973	Clean Air Act/ Stationary Sources	-.12	-.07	+.02	Full price mark-ups; limited earnings increase
ETA (1980)	Minneapolis SMSA/1980s	1977 CAA Amendments/ Particulate Matter, SOx, HC	-.02 to +.01	-.04 to +.02	n.e.	Arbitrary investment displacement assumption; crude employment coefficient
JACA (1980)	Ohio River Valley/1980s	1977 CAA Amendments/ 5 Major Pollutants	-1.27 to +2.54	-0.25 to +3.71	n.e.	No investment displacement; full mark-up
Miernyk (1974)	West Va./ 1975	Clean Air Act + W. Va. Regs/ Particulate Matter Sulfur Oxides	 +1.34 +4.30	 n.e. n.e.	 n.e. n.e.	Lack of price feedbacks

Rose (1981)	San Diego SMSA 1982	1977 CAA Amendments/ 5 Major Pollutants	-.9 to +.4[f]	-.9 to +.4[f]	-.2 to +.3[f]

---

n.e. Not estimated

a/ Where ranges are given (except Rose), ranges reflect year of most favorable and unfavorable impact

b/ Output measured as Total Gross Output except as indicated

c/ Inflation measured in terms of annual percentage change in CPI

d/ See also the discussion of the studies in text

e/ Based on the Index of Industrial Production

f/ Ranges reflect different assumption used in sensitivity analysis pollution control costs and (2) increases in EPA's estimates of the cost of water pollution controls. Over the years common to both studies the range of changes in gross output is larger in the revised projections, while the range of employment and inflation changes are strikingly similar to previous estimates. On the average, GNP estimates are also similar between the two studies. However, the average annual reduction in unemployment is now projected to be 0.4 percent, while the average annual rate of inflation is seen as increasing by 0.4 percent.

Some advocate a substantial reduction in required air pollution control requirements and a consequent reduction in expenditures. In order to assess the impacts of such a cut, DRI estimated the macroeconomic impacts of a 30 percent reduction in air pollution control investment costs to industry by 1987. The results indicate that the aggregate effects of such a scaling back in regulation are essentially imperceptible. Real GNP, wholesale prices and employment would be changed by less than one tenth of one percent. Hence, any significant contraction in the level of air quality regulation is unlikely to yield measurable macroeconomic gains.

The 1976 Chase Econometrics study[11] of the impacts of air and water pollution control costs yielded the most adverse results. The study suggests negative impacts, however, primarily because Chase made the extreme assumption that pollution control investment fully displaces other investment.

Even so, the results for each indicator range from slightly negative to slightly positive. After correcting for the full displacement assumption, we conclude the Chase study indicates that the Clean Air Act is having a very slight adverse effect on output and inflation while generating a significant expansion in employment.

Hollenbeck[12/] studied the effects of pollution control expenditures in 1973. He concluded that the Clean Air Act's effects on all three measures were negligible. Gross output was estimated to have dropped by about 0.1 percent, and employment to have declined by even less. Prices were estimated to have increased very slightly. Even these results, however, most likely exaggerate the Act's adverse effects, because Hollenbeck made the unrealistic assumption that abatement costs are fully passed through to consumers. Also, he studied an early year of the air pollution control program, when many "first time" costs were being incurred and before firms had opportunities to seek cost-reducing innovations and substitutes.

2. Regional Studies

The five other studies were undertaken at the level of the SMSA (Standard Metropolital Statistical Area), state, or air basin. They also differ from the previous three studies in that all but Miernyk's[13/] work examine the effects of increments to control regulations such as the Clean Air Act Amendments.

The impacts projected in regional studies are somewhat larger than in the national studies. This is to be expected, however, because regional economies are by definition much smaller in size, thus resulting in a much larger percentage effect from any significant cost requirement. Also, such effects are not representative of all or even many regions because those which have been examined have tended to be areas characterized by high concentrations of firms significantly affected by Clean Air Act requirements.

A study by ETA (1980) examined the impacts of a State Implementation Plan to comply with costs specific to the 1977 Clean Air Act Amendments in the Twin Cities-St. Cloud area of Minnesota. The impacts are very minor, owing in part to the small increases planned in control requirements. Gains in gross output have been predicted for 1981-82 due to the investment stimulus of pollution control. Note, however, that the actual stimulus may be underestimated due to the study's arbitrary assumption that 50 percent of the investment in control equipment will leak out of the region or supplant ordinary investment. The projected downturn of 0.02 percent for each subsequent year is based on the dampening effect of increases in pollution control operating costs. The timing and relative size of the impacts on employment follow those of output. The results are more tenuous, however, because indirect employment impacts are based on an economy-wide ratio of employment to output.

A study by JACA (1980) examined the economic impacts of a State Implementation Plan (SIP) for the Ohio River Valley. A conventional input-output model, supplemented by the Wharton Econometric Forecasting Model, was used to estimate direct industry production adjustments to the SIP related costs. The results shown in Table 2 indicate a range of output effects from -1.2 percent per year to +2.54 percent per year. Employment impacts are more expansionary, ranging from -0.25 percent per year to +3.71 percent. It must be noted, however, that the expansionary effects presented are exaggerated because they reflect a consolidation of all required investment in a single year and also, that no "crowding out" of conventional investment was assumed. On the other hand, the contractionary effects are also overstated due to the assumption that all pollution control costs are passed on in the form of price increases.

The study did provide an important methodological refinement in distinguishing between gross private control costs after the inclusion of various subsidies (tax credits, industrial development bonds, etc.). Failure to do the same by the other studies reviewed results in an exaggeration of negative impacts as measured by conventional national income accounting practices.

Miernyk, in his 1975 study of the effects of Federal and state sulfur dioxide and particulate controls on the West Virginia economy, concluded that the state's gross output would increase by between 0.6 percent and 1.3 percent per year.

Miernyk used a dynamic input-output model based on empirical evidence that investment in pollution control equipment would fully supplement planned investment in ordinary plant and equipment. However, his model did not account for the possible reduction in purchasing power stemming from pollution control costs being passed on to consumers in the form of higher prices. This restriction has the effect of overstating the beneficial effect of the regulation.

Rose examined the impacts of the San Diego regional control plan elements resulting from the 1977 amendments to the Act, and covering the five major air pollutants. Although Rose also used an input-output approach, he used a technique for incorporating alternative assumptions about the extent of price feedbacks and other secondary effects to reflect the responses of the region's economy to a change in control costs. Rose concluded that in the compliance target year, 1982, these control measures would have an essentially neutral effect on growth, prices, and employment in the region.

Based upon these study results, we conclude that output has remained essentially unaffected by Clean Air Act controls. At worst, effects on output have been only very slightly adverse, less than 0.1 percent per year. Unemployment has declined as a result of clean air legislation, by 0.1 to 0.2 percent per year and consumer prices have increased only very slightly, in the range of 0.1 to 0.2 percent per year. These are the results prior to any effort to take the air quality control program's benefits into account.

D. Economic Impacts After Taking Benefits Into Account

The macroeconomic studies reviewed above employed dynamic, general equilibrium or input-output models to simulate the response of the aggregate economy to pollution control costs. As a result, they fail to account for a large fraction of the beneficial effects of air quality improvement, and they give only a partial assessment of Clean Air Act impacts. Most of the benefits of air pollution control -- prevention of human health effects not reflected in productivity data, protection of visibility and prevention of damage to the natural environment -- are not reflected in market transactions and hence are not recorded by changes in the GNP or prices. In order to reflect the real impact on public welfare, these benefits must be accounted for. Effects on GNP and the other macroeconomic indicators must be adjusted or combined with additional data on the value of these damages to account for the benefits these conventional indicators ignore.

The most comprehensive analysis and synthesis of such benefits undertaken to date is contained in a 1979 report by Freeman, prepared for the Council on Environmental Quality.[14] Freeman reviewed and synthesized estimates of the health and welfare benefits from control of sulfur dioxide and particulate matter. He concluded that controlling these two pollutants alone generates approximately $21.4 billion (in 1978 dollars) in benefits each year. Of this, only about $1.6 billion are in the form of market transactions that are reflected in the conventional macroeconomic indicators. Additional benefits of $19.8 billion are not accounted for by the indicators measured in these studies.

These benefits must be added to Gross National Product in order to reflect the true output of the nation's economy and well being of its people. GNP in 1978 was $2.16 trillion dollars. Addition of the $19.8 billion in non-market output raises the nation's economic welfare by approximately 0.9 percent.

When the macroeconomic studies are adjusted to take these benefits into account, they generally show that the Clean Air Act's net effect on the nation's output is positive. This adjustment is sufficient to counterbalance even the largest adverse impact on GNP projected by any of the nationwide studies. Freeman, in fact, by comparing his $21.4 billion estimate of benefits with the BEA reported cost of $17.0 billion in 1978, concludes that Federal clean air legislation generates $4.4 billion per year in net economic benefits. Hence the Clean Air Act exhibits net benefits in tandem with a very modest impact on aggregate measures of economic activity.

Similarly, conventional measures of the impact of air pollution controls on prices do not take into account the benefits that are not reflected in market transactions. The health and environmental damage from pollution may be seen as a hidden form of inflation. It does not show up in either the Consumer Price Index or the GNP Price Deflator, yet it represents real inflation in the cost of living. The benefits of air pollution control reduce this hidden form of inflation, possibly by enough to counterbalance the impact on prices projected in the macroeconomic studies.

Thus, in order to account for the real benefits of pollution control which are not reflected in market transactions, all of the study results have to be modified to show greater economic growth and perhaps less inflation.

III. The Impacts of Environmental Regulation on Productivity

A number of studies have sought to estimate the effect of environmental regulations on the productivity of labor. Other studies have pursued the productivity question indirectly by estimating the impact of environmental controls on innovation, technological change, and modernization in American industry. The results of these studies are suggestive of the productivity impacts of the Clean Air Act.

A. Labor Productivity Studies

The productivity of labor (which represents the efficiency with which the economy uses its principal resource, human capital) is conventionally measured in terms of GNP per person-hours of work each year. The annual change in labor productivity is generally considered an important indicator of the rate of growth of the economy.

Several authors have argued that environmental regulations dampen labor productivity and, hence, economic growth. In their empirical work, however, these authors have found only very modest productivity declines attributable to all environmental regulations combined.

Haveman,[15] in his recent comprehensive review of such studies, concludes that eight to twelve percent of the decline in productivity since 1972 can be assigned to environmental regulations. The rate of productivity growth declined from 3.05 percent per year in the 1960-1969 period to 1.59 percent per year in the 1970-1979 period. Thus, of the 1.46 percent decline in annual productivity growth, Haveman concludes that all environmental regulations together were responsible for 0.12 to 0.15 percent.

Looking to specific studies, Denison,[16] for example, estimated that all federal environmental programs reduced productivity growth by 0.22 percent per year in the 1972-1975 period and by 0.08 percent per year from 1975 to 1978. This reduction in the adverse effect of all environmental regulation suggests that firms are effectively incorporating controls into their production processes, thus dampening earlier, more adverse, effects on efficiency. Siegel,[17] on the other hand, concluded that environmental regulation had no effect, positive or adverse, on productivity during the 1973-1978 period.

As in the case of the macroeconomic studies of GNP, prices, and employment, none of these authors integrated non-market benefit estimates into conventional productivity measures. Thus they all have overstated the growth-dampening effects of such controls. The small negative productivity effects they assigned to regulation probably would disappear if GNP were adjusted to take into account the benefits of air pollution control and other environmental regulations which are not captured in the conventional GNP measures. In fact, there is a high probability that if adjusted to take account of the $19.8 billion in non-market benefits attributed to air pollution controls by Freeman, these regulations would be shown to increase the real productivity of labor.

B. Studies of Technological Advance

In addition to the evidence of relatively minor productivity impacts of environmental controls in the aggregate, there is significant industry specific evidence that regulation has increased innovation.[18/] Requirements to reduce emissions have forced firms to use scarce factors such as energy, materials, heat, and capital more efficiently. Firms typically respond to these pressures by reassessing their basic production processes, the level and composition of raw material consumption and other factor inputs, and the potential for expanding current markets or moving into new ones.

Recent evidence demonstrates that environmental regulation has had beneficial technology-forcing effects in many industries in the U.S. and abroad. One aspect of this effect is greater interest in recovering resources from wastes. For example, many non-ferrous smelting operations have adopted the "Outokumpu" process for recovery of sulfuric acid from sulfur dioxide emissions.[19/] Refineries are recovering marketable hydrocarbons from emissions and steel facilities are recovering iron dust residues from emissions for reuse in steel fabrication.[20/]

In addition to resource recovery, many firms have utilized the regulatory "nudge" to reassess the efficiency of their manufacturing processes. They have found that the most efficient approach to meeting environmental performance standards is not necessarily to adopt the existing technologies on which EPA standards are based, but instead to incorporate the abatement requirements into revised production and handling processes. This often results in reduced materials, energy, and water consumption, as well. Many actions conserve energy at the same time they reduce pollution: e.g., heat reuse, coupling heat-producing and heat-consuming processes, integrating heat and power production, reducing heat and cold losses and modifying process temperatures, compressor and pump loads, and boil up rates.[21/]

Since 1976, the 3M company has undertaken a comprehensive effort to reduce waste through air and water discharges. The company has reduced its annual air emissions by 20 percent, water effluent by over 90 percent, and solid waste by over 70 percent. At the same time the firm saved $2.4 million from recovered resources and reduced treatment costs. Westvaco has found the recovery of materials from mill wastes so profitable that it created a chemical subsidiary with $45 million in sales in 1980, all from materials previously dumped or burned.

The chairman of Haynes Dye and Finishing Company testified that "cleaning up our stacks and neutralizing our liquids was expensive, but on balance we have actually made money on our pollution control effort. EPA has helped our bottom line."22/

Thus environmental standards appear to be selectively effective in stimulating innovation that lowers the costs of pollution controls and sometimes produces net savings. This further moderates the potential for adverse effects on output, prices, and other macroeconomic measures.

IV. Conclusion

The Clean Air Act has required the expenditure of substantial resources by U.S. firms, governments and individuals. From 1972 to 1979 air pollution outlays (in 1972 dollars) totalled $65.2 billion. These expenditures are, however, much less significant when viewed in the context of the aggregate economy. All private air pollution control outlays in the 1972-79 period represented only 2.7 percent of gross private domestic investment and total expenditures were only 0.6 percent of GNP during that same period .

In addition, the net economic welfare effects of air quality regulations are positive. Evidence drawn from the literature on the value of environmental benefits suggests a net gain of $4.4 billion accruing annually (1978 dollars) from the Clean Air Act when compared to annualized costs.

The impact of the Clean Air Act on aggregate economic activity at the national level is extremely small with some measures adversely affected and others enhanced.

The effect on Gross National Product (GNP) growth is shown by market-based models to be extremely small, imposing a dampening influence of less than 0.1 percent per year. The most comprehensive work indicates that air pollution control legislation has actually had, on balance, an expansionary effect through 1978. The slight contractionary effect overall (for the 1970-1988 period) results from cost increases experienced in the 1978-1980 period and those anticipated for the 1981-1988 period.

The labor productivity impacts of air quality regulation, which closely relate to output growth in the economy, have not been conclusively determined. Conventional growth accounting and regression analyses have shown environmental regulation to have a very slight dampening effect, and have indicated that this effect is diminishing as the regulations are increasingly integrated into investment and production activity. Recent work incorporating non-market benefits into aggregate output estimates suggests that labor productivity has been slightly increased as a result of air quality regulation.

The price impacts of air quality legislation are only modestly adverse. Studies completed to date conclude that the Consumer Price Index has risen by 0.1 to 0.2 percent as a result of mandated expenditures on air quality controls. This result of market based modeling must be tempered, however, by research results which show an increase in non-market outputs (e.g., improvement in the quality of life) due to air pollution benefits. Such results suggest an even more modestly adverse to neutral inflation effect.

The employment impacts of the Clean Air Act are generally concluded to be expansionary. The most recent work indicates the size of the impact to be significant and increasing. Unemployment is shown on average to decline by 0.1 to 0.2 percent per year, with the absolute size of the employment expansion lying in the 300,000 to 500,000 range. This increase results from the regulation induced increase in total investment (conventional plus pollution abatement) per unit of market output as well as the relative labor intensity of air pollution abatement activities.

Air pollution controls appear to have exerted technology advancing pressures in a variety of industries resulting in productivity advances at the firm and sectoral levels. Steel, chemicals, and other industries also appear to have incurred selective technological nudges resulting in production efficiencies as well as several reported cases of reductions in input purchase requirements such as energy, materials, and natural resources.

The Clean Air Act has, on balance, generated beneficial economic effects when non-market health and welfare impacts are appropriately evaluated and incorporated into the assessment framework. These net benefits have resulted despite the failure to explicitly incorporate economic efficiency considerations into air quality legislation. Further pursuit of more efficient regulation by EPA and the states can only increase the already significant net welfare gains realized by the Clean Air Act.

Footnotes

1. Seven industries, namely electric utilities, food processing, iron and steel, non-ferrous metals, chemicals, pulp and paper and petroleum refining incurred 62.5 percent of total air pollution control expenditures in 1978. Costs of Clean Air And Water, U.S. Environmental Protection Agency, 1979.

2. All cost data from Rutledge, Gary L. and Trevathan, Susan L., "Pollution Abatement and Control Expenditures," Survey of Current Business, March 1981, Volume 61, Number 3, p. 19.

3. Economic Report of the President, 1981.

4. Op. cit., Rutledge and Trevathan.

5. Bailey, Martin J., National Income and the Price Level: A Study in Macroeconomic Theory, 2nd. Edition. New York: McGraw Hill, 1971.

6. Sargent, Thomas J., Macroeconomic Theory, Volume in Economic Theory Econometrics and Mathematics Economics. New York: Academic Press, Inc. 1979.

7. Data Resources, Inc. "The Macroeconomic Impact of Federal Pollution Control Laws: 1979 Assessment" July, 1981.

8. Economic Report of the President, January 1981.

9. Ferguson, C.E., Economic Analysis: Theory and Application, Third Ed., Richard Irwin, Inc., Homewood, IL 1978.

10. Mitre Corp., "The Status of the Strategic Environmental Assessment System;" MTR-80W 206, McLean, VA, Sept. 1980.

11. Chase Econometrics, "The Macroeconomic Impacts of Federal Pollution Control Programs: 1976 Assessment," 1976.

12. Hollenbeck, K. "The Employment and Earnings Impact of the Regulation of Stationary Source Pollution," Journal of Environmental Economics and Management, 6, 208-221, 1979.

13. Miernyk, W. Air Pollution and Regional conomic Development, Lexington Books, Lexington, MA, 1974.

14. Freeman, A. Myrick III, "Some Issues in the Estimation and Use of Benefit Measures;" A Report Prepared for the Council on Environmental Quality, February 1980.

Footnotes (continued)

15. Haveman, Robert H., "Environmental Regulations and Productivity Growth," in Environmental Regulations and the U.S. Economy, Johns Hopkins Press, 1981.

16. Denison, E., "Effects of Selected Changes in the Institutional and Human Environment Upon Output Per Unit of Input." Survey of Current Business. January 1978, pages 58-59.

17. Siegel, Robin, "Why Has Productivity Slowed Down:" Data Resources Inc., U.S. Review, March 1979.

18. Scherer, Frederick, Industrial Market Structure and Economic Performance, Rand-McNally, Chicago, 1970.

19. Harkki, S., "The Outokumpu Flash Smelting Method," in Non-Waste Technology and Production, Pergamon Press, Oxford, 1978.

20 Royston, Michael G., Pollution Prevention Pays, (Pergamon Press, Oxford, 1979).

21. Non-Waste Technology and Production, Pergamon Press, Oxford, 1978.

22 Royston, Michael G., Making Pollution Prevention Pay Harvard Business Review, November-December 1980, p. 6.

References

1. Chase Econometrics. "The Macroeconomic Impacts of Federal Pollution Control Programs: 1976 Assessment." (1976).

2. Data Resources Inc. "Macroeconomic Impacts of Federal Pollution Control Laws: 1978 Assessment." U.S. Council on Environmental Quality (CEQ), Washington, DC (1978)

3. Denison. E.F., "Effects of Selected Changes in the Institutional and Human Environment upon Output per Unit of Input," Survey of Current Business, 58, 21-24 (1978).

   ______________. "Pollution Abatement Programs" Estimates of Their Effect Upon Output Per Unit of Input, 1975-78," Survey of Current Business, Part I, 58-59 (1979).

   ______________. "Explanations of Declining Productivity Growth." Survey of Current Business, Part II, 1-24 (1979).

4. ETA Engineering Inc. "The State Implementation Plan Process: Twin Cities-St. Cloud Regional Study. Report to the National Commission on Air Quality, (1980).

5. JACA Corporation. "Air Quality and Economic Impacts for the New York Study. New York-New Jersey-Connecticut Regional Study. Report to the National Commission on Air Quality, (1980).

6. Hollenbeck, K. "The Employment and Earnings Impact of the Regulation of Stationary Source Pollution," Journal of Environmental Economics and Management, 6 208-221 (1979).

7. Jennrich, J. "Environmental Control," Nations Business,December, 72-76 (1979).

8. Kneese, A.V. and Bower, B.T. Environmental Quality and Residuals Management, Johns Hopkins Press, Baltimore, (1979)

9. Kohn, R. A Linear Programming Model for Air Pollution Control, MIT PRess, Cambridge, (1978).

10. Lakshmann, T. and Lo, F. "A Regional Economic Model for the Assessment of Effects of Air Pollution Abatement," Environment and Planning, 4, 73-99 (1972).

11. Miernyk, W. Air Pollution and Regional Economic Development, Lexington, MA. (1974).

References (continued)

12. National Commission on Air Quality. To Breathe Clean Air, Washington, DC., 1981.

13. Portney, P. "The Macroeconomic Impacts of Federal Regulations," Natural Resources Journal, forthcoming (1981).

14. Rose, A. "A Simulation Model for the Economic Assessment of Alternative Air Pollution Regulations," Journal of Regional Science, 17, 327-344 (1977).

15. Rose, A. et al., Assessing the Economic Effects of Implementing AQMP's in California, Vol. 1: Economic Impact Modeling, Final Report to the California Air Resources Board, San Francisco, Public Interest Economics-West, (1979).

16. Royston, Michael G. "Making Pollution Prevention Pay," Harvard Business Review, November-December 1980, p. 6.

17. U.S. Council on Environmental Quality, Eleventh Annual Report, U.S. GPO, Washington (1980).

18. U.S. EPA, "Early Warning Economic Dislocation Reports," Washington (1977).

SELECTED READINGS

SITING

SITING NEW INDUSTRY:
AN ENVIRONMENTAL PERSPECTIVE*

by

Christopher J. Duerksen
Senior Associate
The Conservation Foundation
1717 Massachusetts Avenue, N.W.
Washington, D.C. 20036

October 1982

---

* This article summarizes the forthcoming final report of the Conservation Foundation's Industrial Siting Project, which has over the last three years investigated how environmental and land-use laws affect new industrial development. The author wishes to acknowledge the contributions to this article of Robert G. Healy, H. Jeffrey Leonard, Gabriele Knodgen, Michael Mantell, and Richard A. Liroff and the support of the German Marshall Fund of the United States, Ford Foundation, and the Richard King Mellon Foundation.

INTRODUCTION

In 1968, Kelly Springfield, a subsidiary of Goodyear, took just 13 months from the time it began searching for a production facility site until it started turning out tires in Fayetteville, North Carolina. In December 1975, Standard Oil of Ohio (SOHIO) announced plans to build a major crude oil terminal and pipeline at the Port of Long Beach, California. The project, known as Pactex, needed about 60 environmental permits. Over three years later, in June 1979, SOHIO killed the project citing, among other things, the environmental hurdles the project still had to clear.

Clearly the rules of the game for siting industrial facilities had changed dramatically from the 1960s to the 1970s, and increasingly it seemed that plants were being blocked altogether by environmental regulations. The SOHIO debacle left corporate headquarters across the country buzzing, and politicians were stunned. President Jimmy Carter, no mean environmentalist himself, responded by proposing an Energy Mobilization Board with power to expedite big energy projects by overriding state and local governments and environmental laws. Something important was in the air. Some in industry were claiming the United States had gone too far during the 1970s, when Congress and state and local governments enacted scores of new environmental and land-use laws. They alleged that such laws and regulations were stifling much-needed economic growth and eroding the competitive position of domestic industry. When Ronald Reagan took office in 1981, he picked up the baton: It is time to create new jobs, to build and rebuild industry, and give the American people room to do what they do best." He would soon make clear that environmental regulations were a culprit in our economic decline and an impediment to reversing it.

Even environmentalists would concede that the rules changed in the 1970s. Building industrial plants--even big, heavily polluting ones like steel mills and petrochemical facilities--used to be a fairly straightforward business, with few uncertainties when it came to government regulations. Sites were chosen strictly from a business point of view. How close are the markets? How good are the roads? How expensive is labor? Textbooks on the subject did not even mention environmental regulations. Of course, all that changed beginning in 1970. Serious environmental problems throughout the United States prompted Congress and state and local governments to enact a host of new laws that firms must now consider when they start thinking about a new plant.

While statistics reveal many impressive gains because of these new laws--for example, dramatic improvement in air quality in many urban manufacturing centers--the laws caused a lot of complaints from industry. The new laws and regulations are said to hurt in several ways:

- The large amounts of money spent to comply with these regulations could be spent more "productively" on new capacity and for modernization. These "unnecessary" costs drive up inflation and stifle productivity.

- The costs of these laws and regulations place domestic firms at a serious disadvantage in competing with foreign firms and have led to a flow of capital investment abroad. Lax enforcement in some states has also led to a competitive shift within the United States.
- The sheer complexity of environmental reviews and permitting causes long delays in constructing new facilities, adding not only to project expense but making long-term planning for production and marketing highly uncertain. Moreover, many plants are being blocked completely by environmental regulations.

Ironically, environmentalists are not entirely pleased with the new system. They maintain that while on paper the system looks like it protects the environment, in truth the process, despite being complex and time-consuming, doesn't always guarantee that projects are evaluated adequately or that the environment is protected.

WHAT ISSUES THIS BOOK LOOKS AT AND HOW THOSE ISSUES WERE STUDIED

Must environmental quality be sacrificed in the current rush to economic recovery or in the longer term effort to make the American economy more competitive in world markets? Are environmental laws and regulations really so burdensome, so complex, that nothing short of radical surgery will cure our ills?

To address this issue, the country needs a better picture of just how serious an impact environmental and land-use regulations have on the building of industrial facilities that will play an important role in economic recovery. In recent years, there has been heated debate over both the anticipated costs of proposed regulations and the overall effects of environmental measures on inflation, productivity, and employment.

While that debate is a healthy one and can provide valuable insights, it does not offer much practical guidance about how individual firms that are building new facilities are affected by regulations or how the existing regulatory process might be improved. Moreover, it also fails to take into account the many state and local environmental and land-use controls that are increasingly important in the siting equation. That is where this report fits in. It looks at the following issues:

1. Just how do environmental and land-use regulations affect the siting of individual industrial facilities? Are they so onerous that U.S. firms might actually forego new capital investments or close up shop and go to other states or even to

other countries with more favorable attitudes and laws?

2. Are many industrial projects being delayed or blocked by lengthy environmental reviews?
3. Are there ways to improve the efficiency and effectiveness of the environmental review process for industrial plants?

The project team that addressed these key issues included lawyers, political scientists, and an economist. In addition to reviewing books and reports dealing with siting policy and environmental regulation, this group conducted original statistical analysis, undertook several major case studies, and engaged in hundreds of interviews.

WHO SHOULD READ THIS BOOK?

This book has been written for a general audience--citizens, policymakers, business people, government officials--in short, anyone interested in how industrial growth affects the environment and how environmental regulations affect industrial growth. However, the book is directed primarily toward two types of people: those who plan and build industrial facilities and those who establish and implement environmental laws and regulations--legislators, regulators, and the like.

It is not a scholarly treatment of industrial location theory. Others have written long and well on that very technical subject. Rather this book provides an analysis of regulatory issues based on everyday experience and offers practical advice on how the siting process and relevant regulatory procedures can be improved without sacrificing environmental goals.

THREE MYTHS ABOUT ENVIRONMENTAL REGULATIONS

What We Found Out about The Headline Concerns

There are several "headline" concerns about the impact of environmental regulations that, we conclude, are really only myths obscuring the real path to reform.

Myth No. 1: Environmental Quality Regulations Are Causing Flight of Industry to Other Countries.

Are domestic environmental regulations really so costly and difficult to comply with that U.S. firms are either shopping around for "pollution havens" or are being forced to shut down because of an inability to compete with industry from countries with lax laws? Our research failed to turn up any credible evidence to support the expectation that environmental regulations have or are about to precipitate a significant movement of domestic industry to supposedly low-standard countries. We found that differentials in environmental control costs are outweighed by production and other capital costs. Moreover, other traditional locational factors such as access to markets, proximity of supplies and natural resources, and political stability are in the vast majority of cases far more important than environmental regulations. At most, such regulations are important only on the margin when all other factors are equal--which is rarely the case.

True, we did find examples where individual plants that were blocked in the United States located abroad and that in some situations environmental regulations worked in concert with other factors such as high wage costs or outmoded production facilities to hasten the movement or the demise of a particular plant or sickly industry, but these are isolated instances. In only a handful of industries (notably some primary metal processing industries and those producing highly toxic chemicals such as asbestos and benzidine dyes) has there been a significant erosion of competitiveness due, in part, to environmental laws. Even here, however, it has often been workplace health standards, other than pollution controls, that have had the most effect.

Myth No.2: Industry Moving to New Locations Within the United States Is Lured by Weak Environmental Laws or Lax Enforcement.

The issue of regional competition based on weak environmental laws and differential enforcement has nagged at Congress since the 1960s and helped influence the adoption of geographically uniform federal environmental standards. Congress felt that without such uniformity industries could play one state off against another by threatening to locate where laws were the weakest--

"environmental blackmail," so to speak. The adoption of federal laws quieted the debate over "environmental blackmail" during the early 1970s, but later in the decade the issue flared again.

Isn't it possible, we asked, that, even though lax environmental quality regulations are not an international lure for industry, they might still attract firms to some states within this country? Or that, even if laws were uniform, weak enforcement might be an attraction? As was true with claims about international flight, we concluded "no":

- We could unearth no evidence that environmental and land-use laws had caused a major movement of industry from states perceived to have strong environmental laws to those thought to be more permissive. In the vast majority of cases, we found that environmental regulations were of very minor influence when it came to choosing a location, important perhaps only in breaking a tie between two sites that were otherwise about equal. We also concluded that the final location of controversial projects was more likely to be a result of opposition pushing them away from a particular site, rather than weak laws luring them to another.
- There is a slight, but not statistically significant, tendency of states with less stringent

environmental and land-use regulations to make relative gains in employment in pollution-intensive industries. These states made even clearer gains in manufacturing as a whole, which includes industries highly unlikely to be affected by environmental regulations in making location decisions. This finding suggests that states with less stringent laws or lax regulatory environments may also have other advantages (low labor costs, Sunbelt location, low unionization) that are attractive to industry; it may be these advantages, rather than regulatory laxity, that attracts pollution-intensive industry to them. Interestingly, the state of California, which has some of the strictest environmental laws in the country and a reputation for enforcing them, outstripped all other states in total gain in manufacturing employment during the 1970s.

Myth No. 3: Environmental and Land-use Regulations Are Blocking Industrial Projects across the Nation

Hampton Roads, Pactex, Colstrip, and the Alaskan Pipeline, these are all familiar names and legendary horror stories to the people in industry charged with building new plants. From a sampling of recent headlines, articles, and speeches, one might think that no big industrial projects get built in the United States any longer, falling prey to environmental laws and other assorted regulatory ills.

"Environmental Regulations Kill Pipeline Project Says SOHIO." "A Rocky Road Awaits Industry On It's Way Through The Environmental Obstacle Course." "We Must Cut Through Needless Red Tape Blocking Energy Projects."

One recent study, based on a comprehensive survey of newspaper and magazine articles, seems to lend some support to that conclusion. It claimed that, between 1970 and 1978, 50 percent of all proposals for new or expanded oil refineries were blocked from locating at the site originally chosen and that 58 percent of petrochemical projects were delayed due to environmental problems.

Are things really this bad? Are most big industrial projects in the United States being hobbled by environmentally induced delays? Are we really doing badly when compared to the way other industrial superpowers--Germany, France, Japan--handle their industrial/environmental clashes, as is so often alleged?

What we found was interesting, contradicting the conventional wisdom: A significant number of industrial facilities are being built relatively quickly with few or no environmental problems. These success stories are often overlooked in the clamor over celebrated siting battles. Moreover, environmental and land-use regulations are not the primary cause of long delay in most industrial developments. Even in the headline-making disputes, where plants are blocked or years pass before ground is broken, delays caused by environmental quality regulations are often far less significant than those attributable to lack of consensus regarding need, financing problems, labor disputes, construction and equipment delivery snafus, and regulatory hurdles not associated with environmental protection.

We also reached some secondary conclusions that are important footnotes to the delay issue. First, in many instances where environmental or land-use regulations did delay a project, problems were attributable to what might be called teething pains. Both industry planners and government regulators were, for the first time, faced with complying with or implementing complex laws, and this very newness caused some delay. There is increasing evidence that the number and intensity of environmental conflicts in the United State are slowly decreasing as the players in the siting game learn the new rules.

Second, siting disputes in Europe and Japan appear to be no less in number or intensity than in the United States, and the time taken to approve major projects in those countries is comparable. Interestingly, there is increasing evidence that environmental conflicts may be on the upswing in Europe as the EEC adopts new and more stringent pollution control laws and the "green" political movement gathers momentum.

NO NEED FOR REFORM?

The evidence that environmental and land-use regulations are not the impediment they are often portrayed to be is substantial. Yet, we found several compelling reasons to avoid complacency. Society cannot ignore the significant costs that environmental protection entails, just as it cannot ignore the important benefits. We need to be concerned about the handful of industries that appear to have suffered competitively because of compliance costs. Furthermore, while most economists agree that environmental restrictions do not have a large direct impact on the economy, they are still uncertain about indirect impacts on things like productivity and innovation.

A second "unknown" effect is the possibility of significant investments not being made because business people fear the prospect of environmentally induced delays. While there is no sound method to document the extent of this phenomenon, it was a recurring theme raised in our conversations with industry representatives.

Finally, both environmentalists and business people ask whether the complex regulatory system is effective. Many feel that the protections offered in theory by lengthy reviews are not realized in practice. A time-consuming system that produces mediocre results is a recipe for neglect or for radical changes that no one may really like in the final analysis.

For these reasons, the next step in our study was to look closely at what we found to be the "real" problems in the environmental regulatory system and ways to remedy them, while maintaining environmental protection goals.

THE REAL PROBLEMS AND WHAT TO DO ABOUT THEM

How should we respond to the problems we found in the industrial siting/environmental regulatory process: the uncertainty in the system, the lengthy permit reviews, the prospect of extended litigation and judicial review, and the inadequate analysis of environmental impacts? Regulatory reform is certainly not a new topic. Almost as soon as the ink was dry on environmental laws of the early 1970s, there was talk of reform. But these and later efforts did not fully succeed, and now people ask if the country should adopt the Energy Mobilization Board approach of ignoring certain laws and overriding state and local governments that stand in the way of needed, industrial projects. Should substantive standards be relaxed, a course being advocated by some in the Reagan Administration. Our research leads us to conclude that effective, long-lasting reform lies in an entirely different direction. We believe that a host of "quiet" reforms that focus on procedural and institutional changes are the best alternative and that the current search by some for quick or radical solutions may actually set things back as promising, less-visible efforts are swept aside in the rush to reform.

The emphasis in our report is on these less flashy incremental changes that offer the prospect of faster and more effective project review and permitting over the next five to ten years. The focus is more on procedures and institutional reorganization than on substantive changes in laws or regulations. Thus, rather than suggesting that air emission standards be relaxed or tightened, the report offers methods to ensure that a particular standard is applied to a project in an efficient and effective fashion. Instead of offering a blueprint for a whole new regulatory system--for example, one based on effluent charges (as some economists propose)--we offer advice on ways to oil squeaky cogs in the existing regulatory machine. This means more than just tinkering, however. Some fundamental changes are proposed, for example, in the way corporations plan major facilities and in the way regulators handle project reviews.

Improving Interagency and Intergovernmental Coordination

When most people discuss permit reform or streamlining, they are talking about dealing with the multiple permit/multiple agency problem. One industrial development expert summarized the problem like this:

> ...government at all levels has enacted a hodgepodge of licensing requirements on new industrial enterprises. Although these requirements have been a response to legitimate concerns for protecting our environment, we now have the problem of having to obtain multiple

> licenses from state, federal, and even local agencies. The process is largely duplicative and consumes a large amount of time and money....

This study and many others confirm that lack of intergovernmental and interagency coordination, particularly in the review of large industrial projects, not only lengthens the review process but can result in poor environmental impact evaluation.

What can be done about this widespread problem? A panacea advanced by reformers only a few years ago was so-called "one-stop permitting," where all a project proponent would have to do is go to a single office--a super industrial siting agency--to obtain all necessary federal, state, and local approvals, something akin to a 7-11 convenience store for environmental and land-use permits. As witnessed by the comments of one participant in a 1980 Conference Board session on early corporate environmental assessment, the lure of one-stop permit shopping is still strong among industry officials:

> The key in today's environment of energy, economic, and environmental concerns is just to need one permit. When and how do we achieve it?

An honest answer is probably "never." Industrial projects, especially major ones, affect the concerns of so many agencies and require consultation with so many interests that centralization is probably impracticable. Furthermore, the road to one-stop permitting is filled with deep potholes. Entrenched bureaucracies will fight it, local governments will resist preemption, and in some cases industry may oppose the concept, preferring instead to deal with each agency on its own--a divide and conquer strategy, some critics claim. Because of these and other obstacles, solutions to the multiple permit/multiple review problem will probably be less dramatic and will have to be tailored to each level of government's needs and special requirements. What might work for federal agencies may not fly at the state level, and what succeeds in Georgia may not even get off the ground in California. Thus, we are more likely to see (and, in fact, are already seeing) a wide range of responses:

Consolidation and Reorganization of Agencies or Review Procedures

One method some governments have employed to reduce overlapping or contradictory permit reviews and requirements is to consolidate permitting agencies into a single body, a superagency that has responsibilities for all air, water, land-use, and other environmentally related programs and laws. This approach was adopted by the central government in England when it created the massive Department of the Environment to oversee national land-use planning regulation, pollution controls, historic building preservation, transportation, and housing. A government policy paper explained the underlying rationale: "Because these functions interact, and because they give rise to acute and conflicting requirements, a new form of organization is needed at the center of the administrative system." According to a 1978 report prepared for the state of Maine, 15 states have adopted a variation of the English approach, consolidating pollution control activities and natural resource management into a single entity. An equal number have lodged all pollution control functions in one agency or department, and many have consolidated permit systems for major facilities, particularly power plants.

Consolidation raises many difficult issues. Which agencies should be consolidated and which left alone? What techniques should be used to fuse discrete agencies into a new working body? What sort of internal organization should be created? The experience with consolidation is mixed, indicating that these and other organic issues have not been well addressed and that problems formerly experienced among agencies are sometimes still felt within one new agency.

We found that the more successful state efforts have the following characteristics:

1. Strong administrative support in terms of money and personnel from the governor's office or state legislature.
2. Aggressive pursuit of federal delegation of environmental reviews.
3. Good communication between the government agency and applicants.
4. Permitting agencies that retain an aura of independence from both industry and environmentalists, thereby gaining credibility and respect.

Better Coordination through Better Management

Federal, state, and local agencies are already experimenting with a host of techniques that seek to improve management through everyday techniques used in business to make organizations run more smoothly. Most operate without specific statutory authority, do not create new bureaucracies, add new regulations, or preempt existing laws. We believe this approach has greater promise in the long run than consolidation. Some examples of promising approaches already in use include:

1. Use of expert teams within an agency to evaluate major projects.
2. Use of joint hearings to reduce redundant meetings.
3. Designation of lead agencies to manage the permit process or a mediating agency to help reconcile conflicting positions.
4. Establishment of what might be called "industrial hand-holding and escort services" within state governments that not only help identify needed permits but also set up meetings with regulatory agencies.
5. Appointment of a single contact within an agency to keep track of how permits are progressing and to maintain contact with the project proponent.

However, while using better management techniques sounds like a no-lose situation, they can be counterproductive if not well thought out or implemented with vigor or adequate resources. To some officials, better coordination has simply meant referring a proposal to more outside agencies and bodies and hoping for the best. Informal referrals can be valuable, but they can also slow the permitting process while failing to achieve better reviews. Experience shows that if agencies to whom an application is referred to for comment do not have a commitment to the process, they will often "sign-off" with minimal or no review, particularly if their workload is already heavy and they are not accountable for a final approval or rejection.

Other Governmental Responses

Governments at all levels can initiate other quiet reforms to improve the efficiency and effectiveness of the regulatory process.

Industrial projects are sometimes delayed because companies cannot quickly learn what permits are needed, and when, or get bogged down because regulations change in mid-project. Other times reviews are drawn out because regulators simply do not have sufficient time to handle all the projects assigned to them. Such problems can doom a project from the outset or foreclose a project proponent from getting a "yes" or "no" answer in a timely fashion, thus putting capital commitments into limbo. What can be done to make the permit process more navigable and inject discipline and certainty into the system without unduly tying the hands of regulators or sacrificing quality review? We identified a number of reforms already being put to use in several jurisdictions and agencies at all levels of government.

- Use of permit registers and how-to books to advise companies of what permits they need, from whom, and when.
- Use of voluntary decision schedules to help keep reviews on track while fostering cooperation between regulators and project proponents.
- Careful use of "grandfather" clauses that protect industry from regulation changes once a project has started, unless it can be shown that such changes are demanded by health concerns.
- Use of conditional permits for run-of-the-mill projects. If a project of this sort meets preestablished standards, it can proceed without detailed review, thus freeing regulators to concentrate on major, more complex projects.

It is also apparent that problems in the regulatory system arise because that process does not always mesh well with the needs of corporate project planning. For example, a state agency, with good reason, may want to know what air emissions it can expect from a multi-plant project once it is fully developed. Industry responds by saying it can't be sure beyond the first plant or two, because markets might change, necessitating changes in plant design. In other cases, regulators want detailed design data early on, seeing it as a key to avoiding later enforcement problems. Industry responds by saying it cannot afford to provide detailed information without some sense that the project ultimately will be approved. A company may also balk at revealing detailed information on the ground that it might give away trade secrets. These are difficult issues, but there are ways to ease their impact:

- More cooperation between government regulators and industry in establishing permit review schedules, on an industry-by-industry basis, that mesh with corporate project planning schedules.
- Use of outline approvals by regulatory agencies to indicate general agreement on the major elements of a project, with details to be worked out later. Such outline approvals are widely used in the local land-use regulatory process for residential development.
- More careful handling of trade secrets by regulatory personnel and use of private rulings (similar to those used by the Internal Revenue Service), whereby agencies would review projects and make preliminary rulings without publicly disclosing the facts of a particular case.

BEYOND GOVERNMENTAL REFORM: THE NEED FOR BETTER INFORMATION AND BETTER CORPORATE PLANNING

While these government reforms will help make the process more efficient and effective, they will not solve all the problems we identified. In fact, the fallacy of many recent reform initiatives is that they look to government for all the answers, assuming that by tinkering with organizational charts or procedures all the problems will disappear. While the importance of government's cleaning up its own house cannot be underestimated, we concluded that the necessity for better information in the regulatory process and the need for a revamped corporate approach to planning and building industrial projects are of equal importance, and that to ignore them while pinning all hopes on reforming government will only lead to failure.

The Need for Better Information

Some of the most bitter siting disputes we studied could have been avoided or at least defused if both project proponents and regulators had had better information upon which to evaluate the impact of facility proposals.

In some instances, a company stumbled into an environmental hornet's nest because it was not aware of critical natural resources in the area that the project might adversely affect. We see an increasing need for programs that identify sites in a region that are off limits to developers or that specify those with a "fighting chance" to receive development approval. While much of the country is "uncharted" from an environmental resource point of view, there are some bright spots. Federal agencies such as the Bureau of Land Management and the Forest Service have been surveying their lands over the past few years to identify critical environmental areas and historic and archaeological resources. These inventories, while far from complete, should help industry avoid disputes when proposing projects on federal lands.

The idea of identifying acceptable sites for industry is also embodied in federal coastal zone legislation. Before state coastal zone management plans can be approved, they must identify sites of unique geologic or topographic importance to industrial development and ensure that facilities of greater than local concern are not arbitrarily or unreasonably excluded or restricted. Federal agencies have also recently completed a detailed resource survey of the Atlantic Coast that should be very valuable in project planning.

With the recent federal and state cutbacks in funds for such surveys, it is clear that industry will be called upon to contribute more resources --either people, technical advice, or money--to them or face the alternative of slower reviews or increased opposition to individual projects that opponents feel have not been assessed adequately.

The information gap has a flip side. Regulators often lack necessary information to make informed decisions or are so inexperienced that they do not understand the industry they are supposed to be regulating. As a result, projects may, on one hand, be held up until such information is available or, on the other, may be approved without adequate review and left open to legal challenge. This problem has several roots. In some instances, as noted earlier, the regulatory and corporate project planning process are not synchronized. Regulators want detailed information early, while corporations generally want some sign of approval before proceeding with costly design work. In other instances, agencies lack necessary information because they failed to identify crucial issues early in the permitting process. And, even when issues are identified, the agency involved may lack resources to gather and evaluate the data it needs (particularly at the local level). Moreover, regulators are often "rookies" with little experience, prestige, or pay and are overwhelmed when faced with major industrial projects.

There are no easy solutions to these particular problems, but there are several steps to help reduce their impact:

- Greater use of informational preapplication meetings between company officials and regulators.
- The use of a "scoping" process, whereby agencies from various levels of government get together early in the permitting process to identify key issues and assign responsibility for studying them.
- Technical aid for government agencies, particularly at the local level, to ensure adequate reviews. Such aid would come from the federal and state governments as well as industry.

- Contribution by industry to educational efforts aimed at regulators and run by universities or other neutral third parties to explain production and operational processes for particular industries, project planning needs, and special environmental considerations.

What Industry Can Do

The role of corporations and the private sector is usually overlooked in discussing ways to improve the regulatory system. Our research indicates that, while governments at all levels have a crucial role to play, their efforts alone will almost certainly fall short. Some of the more important changes we think successful companies will adopt include:

- A more open project planning process, with early government and citizen participation.
- Greater attention to land-use and secondary growth impacts of projects.
- More sophisticated internal organization for planning projects, including earlier involvement of environmental specialists and appointment of a single project manager with clear authority to deal with government regulators ~~and citizens~~.
- Increasing use of alternative methods to settle siting disputes such as mediation, incentives, and cooperation.

Clearly, the secretive, behind-the-scenes method of siting facilities that was commonplace in the 1960s will not pass muster in the 1980s. Already we find a number of companies adapting to the new circumstances. An example is the innovative planning approach used by AMAX, Inc., for big mining projects, which stresses openness and cooperation rather than confrontation and preemption. In one case, AMAX signed a formal agreement with local, state, and federal officials that calls for, among other things, early disclosure of all company proposals. AMAX feels that by discussing its plans before they are set in stone--for example, the company offered several alternative sites for a controversial tailings pond at one project--it has a better chance of defusing opposition.

To be successful, corporations will also have to pay attention to the secondary growth impacts of their projects--the development and growth likely to be attracted to an area by a major energy or industrial facility. AMAX and several big energy companies have been particularly sensitive to the secondary growth impacts of their projects in Colorado. For example, at one site AMAX has made strategic purchases of land for housing, with an eye towards reducing sprawl that could affect agricultural and scenic resources and put a tremendous burden on local infrastructure. It has also contributed to the local government's effort to update the county land-use plan. Each of these initiatives has helped allay local fears that

Gunnison, Colorado, the site of the proposed molybdenum mine, will become another boom town like Rock Springs, Wyoming.

Several companies are also becoming particularly sophisticated in the way they manage projects internally. While industry often rails that government agencies are poorly organized to deal with big projects, regulators voice similar complaints about industry. The companies with the best track record have established clear lines of authority so that government agencies can deal with a single project manager rather than a host of public relations people, scientists, engineers, and front-office personnel as has often been the case with big projects in the past. In our research, we found that a key factor contributing to delay was that companies often failed to put one person in charge who could deal authoritatively with government agencies. Progressive firms have also made certain that environmental specialists are brought into the earliest stages of project planning so that they can flag potential problems for top management and advise of potential risks before capital investment decisions are made or sites selected.

Smart firms are also helping the regulators regulate them by providing necessary technical information and making certain that the agencies adhere to their own regulations and standards. This is particularly important when local governments with little experience regulating a major project are involved.

In sum, we found that the worst thing a project proponent can do is to try to rush things through and cut corners, because all it takes is one disgruntled person to sue. Telling firms to, in effect, hire good lawyers or consultants who know the regulatory system through first-hand experience may seem somewhat less than profound, but simple mistakes have led to an uncommon number of problems in big siting cases.

Companies would also be wise to consider alternative means of settling disputes when they do arise. An increasing number of firms are already embracing a resolution mechanism called "mediation," a voluntary process in which disputing parties together explore issues dividing them and which promises to keep environmental battles out of court. While the use of mediation is not widespread as yet, it has helped head off battles over water-related developments along the Columbia River and end what was perhaps the longest-running environmental controversy in the nation--Consolidated Edison's pumped-storage power plant near Storm King Mountain in New York.

Another method to resolve disputes nonjudicially is through the use of incentives, financial and otherwise, to mitigate potential adverse impacts and thus persuade opponents to accept the proposal. During the 1970s, sophisticated residential developers routinely used incentives like constructing community facilities to persuade local governments to approve their projects. That concept is now being applied to major industrial facilities. For example, potential local opposition to a huge energy project in Rio Blanco County, Colorado, was defused when the project proponent agreed to contribute money toward ameliorating secondary growth impacts expected to accompany an influx of workers into a sparsely settled area. The Grayrocks dam controversy in Wyoming and Nebraska is another example. There, the project developer won approval from environmentalists by establishing a trust fund to protect whooping cranes threatened by the dam.

Of course, many big industrial projects have built-in "incentives"--increased property tax revenues and economic activity through a multiplier effect to name only two. But, increasingly, development makes someone unhappy. The local government may be pleased with the project because of a larger tax base, but that revenue may mean little to environmentalists who are worried about saving an ecologically important wetland. The answer in such cases may be to undertake mitigative efforts to keep them happy.

SOME THOUGHTS ON IMPLEMENTATION

While the "quiet" reforms offered here involve far less disruption and change than some of the more radical initiatives now being discussed around the nation, they still must be implemented thoughtfully and with great care. If the proper foundation for change is not laid, the quiet reforms may never get off the ground, or even if they do, they may not work. Our research identified four important considerations in implementing reforms:

1. Maintain the integrity of the system. The public and potential participants must have confidence in the system. If not, the likelihood that change will improve anything is diminished. One way to do this is to involve all interested parties in designing the reforms.
2. Take a comprehensive rather than a piecemeal approach. Comprehensive reform packages have a better chance of success than those that focus exclusively on one problem (as the early one-stop permitting initiatives did).
3. Give reforms high visibility and adequate financial and administrative support once in place, but do not politicize them so that they are discarded by a succeeding administration.
4. Don't expect perfection the first time around.

CONCLUSION

Although some of the proposals discussed here are far-ranging, there are limits to what can be accomplished through procedural and institutional reforms. Even if the system is made as efficient as conceivably possible, getting industrial projects built will still take time--one industry official estimated that it would take four to five years to plan and construct a petrochemical facility even if all regulations were repealed--and there will still be some rejections on environmental and land-use grounds.

Current regulatory reform efforts advanced in Congress and by the Reagan Administration do not hold a great deal of promise in getting at the real problems, which is unfortunate given the current national mood to make government more efficient. The downgrading of environmental review offices in federal agencies, the continual bureaucrat bashing that leaves regulators demoralized, the reduction in funds to undertake research needed to establish sound substantive standards and money for resource surveys, and the deemphasis on enforcing environmental laws may well have political appeal, but they hold little hope of improving the process in the long run.

The continued popularity of environmental protection programs, as reflected in numerous public opinion polls, and the experience in Europe, where a grassroots movement is forcing governments to adopt U.S.-style laws and standards, should make clear that this country is unlikely to return to the old ways of siting industry. The old saying about not being able to go home again rings true here.

The most promising methods of improving the efficiency of the environmental and land-use regulatory system are those that stress cooperation and negotiation rather than preemption and pronunciamentos. The innovative initiatives discussed here offer relief without deforming the system, but will work only if all the players in the siting game cooperate.

TABLE OF CONTENTS OF FORTHCOMING BOOK

I. Introduction: Siting New Industrial Plants--Changing the Environmental Rules

Why all the concern about industrial growth? Are environmental and land-use regulations a roadblock to economic recovery? How such regulations are thought to affect industries and the economy. The implications of industrial growth for the environment.

II. Three Myths About Environmental Regulations: What We Found Out about the Headline Concerns

A close look at several myths about how environmental and land-use laws affect the location of industry. Foreign vs. domestic firms. Interstate competition. Reasons for project delays.

III. Siting Industrial Facilities--How the Process Works

How industrial facilties were planned, built, and regulated in the 1960s compared to today. Case studies of facility siting disputes.

IV. A Short History of Reform Efforts

The forces behind early reforms. Characteristics of such reforms. Why they fell short.

V. Dealing with the Real Problems: A Remodeled System for the 1980s

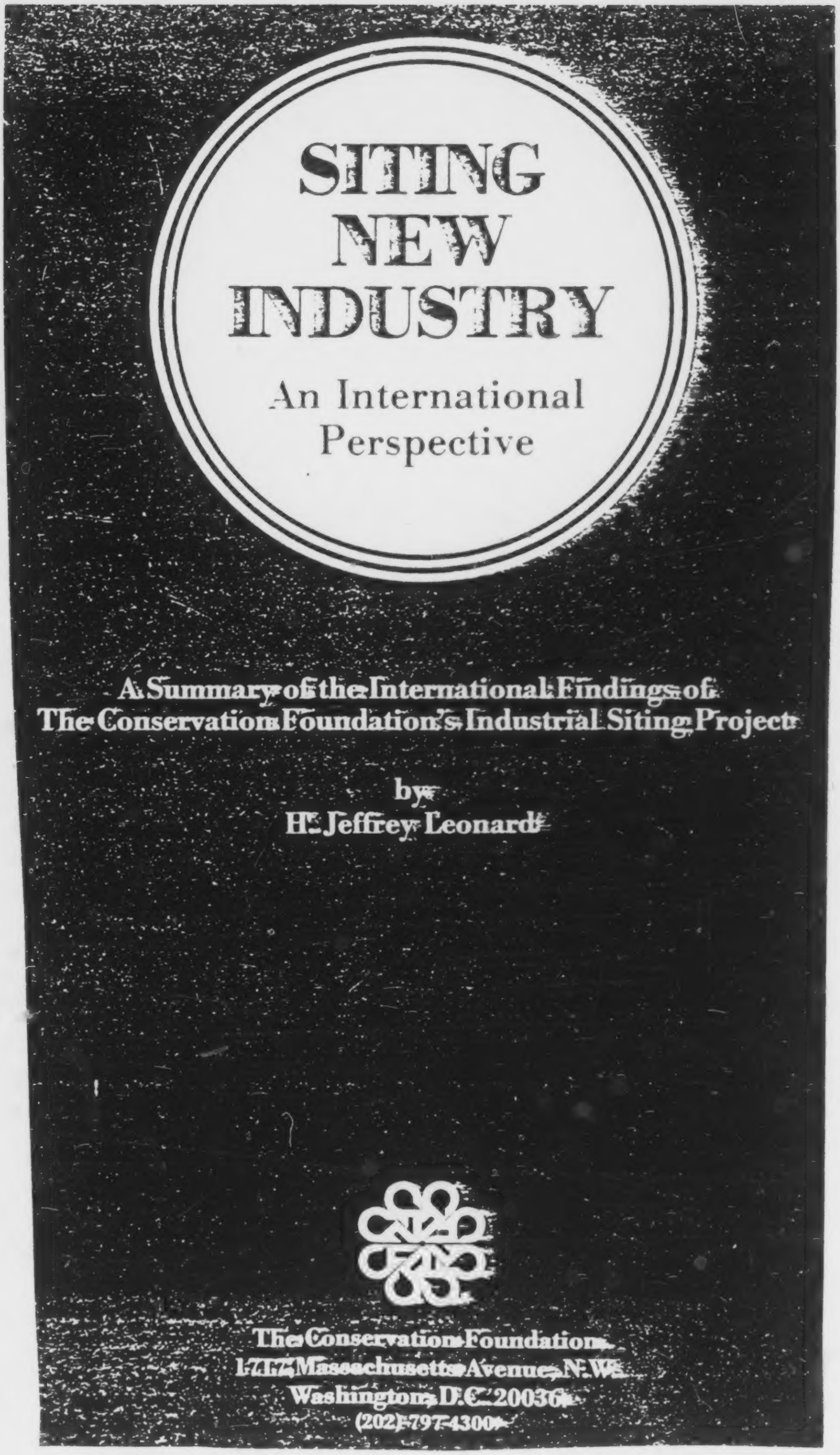
What are the real problems in the siting regulatory process? What can be done about them. Examples, statistics, evaluation, and analysis.

VI. What the Foreign Experience Teaches

Case studies of foreign siting disputes. Lessons.

VII. Reforming or Deforming: Sizing Up The New Regulatory Relief Initiatives

Discussion of recent regulatory relief initiatives. Do they address the real problems? Prospects for success.



SITING NEW INDUSTRY

An International Perspective

A Summary of the International Findings of
The Conservation Foundation's Industrial Siting Project

by
H. Jeffrey Leonard

The Conservation Foundation
1717 Massachusetts Avenue, N.W.
Washington, D.C. 20036
(202) 797-4300

Introduction

Federal regulations covering the pollution of air, water, and land, the manufacture and use of hazardous and toxic substances, and workplace health and safety forced industries in the United States to expend huge amounts of capital and induced fundamental changes in the domestic structure of many industries in the 1970s. Even before many of these new environmental regulations* had been fully implemented, it was obvious that some industrial firms in the United States were spending more for pollution abatement and industrial safety than firms in many other industrialized countries, especially those in the underindustrialized countries outside of Western Europe and Japan. Moreover, industry spokesmen claimed not only that environmental control costs were high, but that the new regulations made it increasingly difficult to build and operate production facilities even when large amounts of money were spent on pollution control.

---

* Although our original research focused primarily on the effects of pollution control and land use-regulations, the broad term "environmental regulations" in this summary also includes workplace health and safety regulations.

As a consequence, many observers within the United States expressed concern that the costs and logistics of complying with environmental regulations might be emerging as a significant factor in the competitiveness and location of industries involved in world trade. While proposing very different policy solutions, policymakers, labor unions, business leaders, environmentalists, and academics all predicted that strict domestic environmental standards might adversely affect U.S. industry's ability to compete with imported products and in foreign markets. It was expected that one response to such competitive problems would be for American firms, particularly multinational corporations with experience operating overseas, to shift more productive facilities to countries where regulatory difficulties could be minimized.

Concerns about Industrial Flight

Two major concerns were raised as a result of the prospects that environmental regulations in the United States would stimulate the flight of manufacturing industries to other countries. The first was that the trend could have adverse effects on the U.S. economy and the overall industrial base. It was feared that employment, the balance of trade, and even national security would be threatened if substantial numbers of U.S. industrial corporations transferred production abroad in response to high environmental costs. Second, concern developed that U.S. firms would take advantage of the desperate desire for industry in developing countries and set up factories that polluted the atmosphere and the water, ignored worker health and safety considerations, and caused other serious environmental hazards in the Third World.

These debates have intensified over the last several years as a result of: continuing low output and high unemployment in many large industries that have been hit with high regulatory costs; increased efforts by industry and now the Reagan Administration to water down or restructure government environmental regulations; growing emphasis on stimulating U.S. exports; and talk about the need for a reindustrialization of this country. Frequently, industry groups have pointed the finger at environmental regulations for depressing the financial outlook of many domestic industries, making it more difficult for U.S. firms to compete with firms from other countries, constraining or actually reducing overall American productive capacity, and thereby pushing increasing numbers of U.S. firms to locate abroad.

In addition, environmental and labor groups, worried that U.S. companies are moving to other countries to "escape" U.S. environmental regulations, have made an effort to follow American companies around the globe and examine their environmental records. Some of the examples publicized in journalistic reports have offered evidence of American companies creating pollution, workplace health, or community wide environmental problems in host countries.

Proposed Policy Solutions

Even though no evidence has been published demonstrating that these trends are, in fact, significant, government policymakers have tended since the mid-1970s to operate on the assumption that environmental regulations have led to an increased exodus of U.S. industries. For example, the effects of pollution and workplace health regulations on American industry were explicitly addressed by U.S. negotiators in 1979 at the Tokyo Round talks on the General Agreement on Tariffs and Trade (GATT). President Carter's chief trade negotiator, Robert Strauss, urged representatives at the trade talks to consider pollution and workplace health standards in light of a "pattern of flight" by industry to countries with low standards. While cautioning against a new protectionism, Strauss said: "American standards in these areas are among the highest in the world, and we do not want this U.S. willingness to protect the environment and our workers to disadvantage the various U.S. producers willing to pay such costs."

Two successive Administrations have devised broad strategies to respond to their perceptions that pollution and workplace health regulations are responsible for increasing the numbers of plants built abroad by U.S. companies. The Carter Administration tried to secure international agreements to equalize pollution control regulations. It also explored possible methods of reducing "industrial flight" and ensuring that U.S. companies would take anti-pollution measures in overseas producing plants. By contrast, the Reagan Administration has approached the problem of industrial relocation as one that must be solved by loosening regulations within the United States. Rather than trying to bring the rest of the world up to our standards, the post-1980 remedy has been to offset relocation pressures from within the United States by rolling back regulations that industry has targeted as burdensome.

What is ironic about the fact that the policy emphases of the Carter and Reagan Administrations differ so much is that both have proceeded on a similar assumption: that environmental regulations are responsible for significant declines in the competitiveness and productive capacity of U.S.-based firms, for increases in imports of manufactured products, and for increasing the number of U.S. industries locating abroad.

Empirical Analysis Lacking

Curiously, the policies proposed in recent years to deal with problems of international competitiveness facing U.S. industries with significant environmental difficulties have not been based on any definitive research into precisely what the locational aspects of those problems are. In spite of extensive advocacy from labor, environmental, and business interest groups, policymakers do not have a good sense of whether environmental regulations have been the driving force, a contributing factor, or merely incidental in international location decisions.

Since 1979, The Conservation Foundation has monitored key U.S. industries to assess whether, in fact, there is any indication that large numbers of U.S.-based industries have been pushed abroad by environmental regulations and whether the U.S. industrial base has thereby been negatively affected. This issue has significant bearing on critical ongoing national policy debates: revision of the Clean Air Act, proposals for weakening numerous other environmental regulations or for relieving particular industries from certain regulations, and proposals for stimulating "reindustrialization" of the United States.

In addition, we have conducted case study research in several rapidly industrializing countries that are among the favorite locations for new factories built by U.S. multinational corporations. This research has attempted to assess what measures U.S. firms take to protect the environment and workers in their overseas plants and what impacts U.S. companies have on pollution and worker health problems in these countries.

Research Findings

Our research indicates that there have been some increases in overseas location by a small number of manufacturing industries in response to pollution controls and (even more so) to workplace health standards. There are also cases in which U.S. firms operating abroad have failed to take measures to reduce pollution and protect worker health.

However, what is most significant is that our research shows these phenomena to be isolated exceptions rather than widespread occurrences. Our investigation of recent overseas investment and foreign trade patterns by U.S. manufacturing industries provides compelling evidence that, where the problems do exist, they are generally more complex and less susceptible to blanket solutions than indicated in recent policy proposals considered by Congress, the Executive Branch, and various advisory groups. Three overall conclusions are apparent from the research:

I. Environmental Regulations Have Not Caused a Significant Exodus of U.S. Industries.

Our investigation of recent overseas investment and foreign trade patterns by U.S. manufacturing industries from 1970 to 1981 shows that:

- At an aggregate level, no signs of a large-scale movement abroad by U.S. based industries can be detected at this time; nor, despite the enactment of numerous environmental laws, have the overall overseas investment patterns of U.S industries changed significantly during the past decade.

- In fact, total overseas investments by the two groups of manufacturing industries that appeared most likely to be pushed abroad by increased pollution control costs and regulatory restrictions--chemicals and metals--have not expanded any faster than those of all manufacturing industries.

- For the most part, the favorite foreign locations of these "pollution-prone" industries remained in other advanced industrial countries, where environmental regulations are generally on or near par with those in the United States.

- Imports for the chemicals and metals industries (which should be rising rapidly if substantial numbers of firms were shifting abroad to produce goods for the U.S. markets) did not expand as fast as total U.S. imports of manufactured products; overall exports by the chemicals and metals industries grew much faster than imports.

- However, when foreign investments and imports for only the primary metals industries are examined, trends toward faster than average expansion and higher percentages of investment in and imports from less developed countries can be detected.

Although environmental regulations have had major economic impacts on U.S.-based industries, our research indicates that regulatory burdens have not been substantial enough to offset the advantages of producing in the United States in most cases. In other words, regulatory costs have not overridden more traditional factors -- market considerations, transportation and labor costs, political stability -- that determine how most firms select overseas locations for branch plant construction. However, the exception of primary metals and the possibility of small-scale changes in specific parts of the chemicals industries prompted us to investigate a number of specific chemicals and metals industries.

II. A Few Industries Do Appear to Have Been Pushed Abroad.

When one breaks down the aggregate figures for the chemicals and metals industries, it appears that most individual industries within these groupings have responded to environmental regulations with technological innovations, changes in production processes or raw materials, more efficient process controls, and other adaptations that have proved more economical and less drastic than flight abroad from the regulations. Nevertheless, a small number of industries do appear to have been influenced by environmental factors to move more production facilities abroad in recent years. The industries most affected appear to be of two types:

- Environmental regulations have severely curtailed new plant construction and in some cases disrupted domestic production of a small number of highly toxic, dangerous, or carcinogenic products, such as asbestos, benzidine dyes, and a few pesticides.

These industries have not as yet been able to develop safer substitutes or to meet environmental, workplace health, and consumer standards easily by technological adaptation.

- Also affected have been basic mineral processing industries such as copper, zinc, and lead, as well as a small number of producers of organic chemical intermediates. In these industries, environmental factors have combined with other changing locational incentives (raw material availability, international product cycle) to speed the international dispersion of the industry.

Our investigation into the ways in which industries have adapted to pollution and workplace health standards, and whether relocation abroad has been one means of adaptation, yields two further conclusions:

- Although we originally focused on the impacts of pollution control costs and project delays resulting from complex environmental regulatory requirements, most of the handful of industries experiencing international dislocations have been hit harder by workplace health standards than by pollution regulations.

- An important point, however, is that we found no significant examples of industrial flight from pollution or workplace health standards in industries where product demand is expanding and U.S. producers enjoy technological superiority. Of the few industries experiencing international dislocations as a result of these standards, most are also experiencing declines in product demand, lagging in technological innovation, and earning inadequate profits for substantial new capital investments.

III. Most Newly Constructed Plants Owned by U.S. Companies in Rapidly Industrializing Countries Overcomply with Local Environmental and Workplace Health Standards.

A small number of countries account for the vast majority of U.S. chemicals and metals investments outside of Canada, Japan, and the highly industrialized countries of Europe. Two still underindustrialized European countries, Ireland and Spain, along with Mexico and Brazil account for over one half of all investments by U.S. chemicals and metals industries outside of the highly industrialized nations. What is more, U.S. investments in these countries have grown quite rapidly in recent years. If U.S. firms have fled the United States in search of pollution havens outside the advanced industrial countries, even if in numbers too small to have macro impacts on U.S. statistics, these few rapidly industrializing countries are prime suspects.

However, our case study research in three of these rapidly industrializing countries--Ireland, Spain, and Mexico--shows that:

- Most American firms that have established branch plants in these rapidly industrializing nations in recent years appear to have taken anti-pollution measures beyond those required by laws in the particular countries. In part, this is because the plants generally are very similar to those built in the United States and the technologies transferred by the firms take advantage of advances already made at home. Also, since most firms expect their plants to last from 20 to 40 years, they are unwilling to bet that environmental regulations will not be significantly stricter during the lifetime of the plant.

- Thus, many U.S. manufacturing facilities abroad are significantly cleaner than plants operated by domestic entrepreneurs. By introducing new pollution control technologies, training technicians in pollution control, transferring technical data, and even sometimes building joint waste treatment facilities with local governments, U.S. companies have in many instances had a positive impact in combatting industrial-related pollution problems in industrializing countries.

- Furthermore, companies that have chosen to operate abroad by ignoring environmental and public health considerations have frequently faced very serious economic and political problems in these rapidly industrializing countries. Our research has discovered examples of U.S. firms being closed, fined, or slapped with new restrictions in all three countries as a result of their failure to take actions to protect the environment and worker health.

Policy Implications

The research summarized here indicates that the costs or logistics of complying with environmental regulations are not emerging as decisive factors in most industrial decisions concerning desirable countries for branch plant locations or in the international competitive picture of most industries. There is no reason to believe that the major long-term trend in international industrial location--the gradual shift of many industries from the most industrialized to rapidly industrializing countries--is being significantly intensified by environmental regulations in the United States.

This finding does not mean that environmental regulations have not burdened U.S. companies; nor does it mean that environmental regulations are not important in the industrial location process. It means that if the differentials in the costs of complying with environmental regulations in industrialized and industrializing countries are an influential factor, they have not offset larger trends shaping aggregate international industrial siting patterns.

There are only a relatively small number of U.S. industries whose international location patterns have thus far been significantly affectd by the stringency of environmental regulations in the United States. In some cases, ongoing trends -- such as backwards integration by metal processors or worldwide purchasing of chemical intermediates--appear to have been speeded up by environmental factors. In other cases, firms within a particular industry appear to have consciously adopted a pattern of flight as an alternative to modernizing plants, developing new technologies, or installing expensive pollution control equipment. Yet, many of the examples we have examined indicate that such industries are often ones that are experiencing static or reduced demand as a result of product obsolescence or hazards related to product use and therefore find few incentives to make new investments within the United States.

A few broad policy implications are apparent from these conclusions:

- Any effort within Congress or the Executive Branch to rollback, weaken, or fail to enforce existing environmental regulations cannot legitimately use the argument that a significant amount of U.S. productive capacity in manufacturing industries has been shipped abroad as a result of the stringency of regulations here.

- In fact, relaxation of regulatory standards, by reducing incentives for technological progress and manufacturing process changes, would not have the desired effect of restoring the long-term competitiveness of U.S. industries experiencing pressures for industrial flight.

- For U.S. firms operating abroad, there may be short-term benefits from cost savings made by failing to take anti-pollution and other environmental protection measures. But these often are offset by the need to make expensive technological adjustments at a later date and by the political problems associated with the expectation in other countries that American firms are supposed to be much cleaner than all others. This means there is a strong self-interest for American companies to take ample steps to safeguard the environment, workers, and the public at large in all countries -- regardless of the regulatory climate in each country. Paradoxically, it also means that U.S. firms, more than those from any other countries, have a vested interest in seeing that realistic pollution and workplace health regulations are enacted and enforced in countries where they operate production facilities.

o For rapidly industrializing countries, consciously maintaining low environmental standards in the hopes of attracting new industries may be an economically unwise strategy. There is a real danger that the few industries that may find such an inducement attractive are industries producing products that are obsclete, extremely hazardous, or subject to consumer standards -- all of which could reduce consumption and therefore export markets in the United States.

SELECTED READINGS

BENEFIT COST ANALYSIS

EPA-600/5-78-014

CRITICAL REVIEW OF ESTIMATING BENEFITS OF AIR AND WATER POLLUTION CONTROL

By

A. Hershaft (ed.)
A. M. Freeman III
T. D. Crocker
J. B. Stevens

Contract No. 68-01-2821

Project Officer
Thomas E. Waddell
Office of Research and Development

Prepared for

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF HEALTH AND ECOLOGICAL EFFECTS
OFFICE OF RESEARCH AND DEVELOPMENT
WASHINGTON, D.C. 20460

DISCLAIMER

This report has been reviewed by the Office of Research and Development, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

PREFACE

This report is submitted in fulfillment of U.S. EPA contract #68-01-2821. It contains a critical review of current methods and data employed in estimating benefits of air and water pollution control.

In order to provide a balanced perspective in assessing the state-of-the-art in the "benefits area", the material in this report is derived from three types of sources:

- Extensive experience by three distinguished consultants in conceptualizing and analyzing benefit estimates;
- Recent experience in preparation of national benefit estimates by the Enviro Control staff; and
- A two-day conference on benefit estimation involving some 25 participants from a number of government, academic and private research institutions.

The three consultants on general benefit estimation, air pollution control, and water pollution control benefits were, respectively:

- Dr. A Myrick Freeman III
  Dept. of Economics, Bowdoin College
- Dr. Thomas D. Crocker
  Dept. of Economics, University of Wyoming
- Dr. Joe B. Stevens
  Dept. of Agricultural and Resource Economics,
  Oregon State University

The Enviro Control contributions, including preparation of the overview, as well as coordination and editing of the three papers, were made by Dr. Alex Hershaft, Director of Environmental Studies, with the assistance of Mr. H. Theodore Heintz, Jr., Senior Economic Consultant, and Mr. Gerald C. Horak, Staff Scientist. Ms. Anita Calcote was responsible for typing and production of the report. Valuable guidance on content and format was provided by Mr. Thomas E. Waddell, the U.S. EPA Project Officer.

ABSTRACT

This report provides a critical review of the current state of the art and future prospects of estimating benefits of air and water pollution control. Benefits of controlling air and water pollution arise from gains resulting from improvements in air and water quality. Such gains can be the reduction of damages caused by pollution or the increase in options now feasible because of improved environmental quality.

This report represents three independent critiques by three experts. Benefit assessment methodologies were evaluated for the following benefits categories: human health, recreation and aesthetic properties, productivity, materials, and natural ecosystem perturbations. Specific aspects discussed include the nature and role of benefits, damage functions, valuation of effects, aggregation of results, and representation of uncertainties.

The conceptual foundations of estimating pollution control benefits were presented and compared with empirical studies. It was concluded that while available estimates often do not adequately reflect the state of the art, estimates of pollution control benefits would potentially be very useful to decision makers. The conceptual basis provided by economic theory for benefit estimation is adequate in most respects and far ahead of the corresponding empirical effort. A number of studies are guilty of failing to list explicitly critical assumptions or to express adequately uncertainty in the results, while other studies have employed conceptual models that are inappropriate to the problem at hand or the available data. It was also concluded that damage functions underlying benefit estimates are frequently based on insufficient data and/or inadequate characterization of exposure and effects. National benefits estimates were found to be based on regional studies which are frequently inadequate in number and/or quality.

For improving general estimation of benefits it is recommended that funding for benefits estimation research be reassessed in light of its potential utility to decision-making process, that a comprehensive national plan for closely coordinated regional benefit studies be developed and implemented and that *ex post* evaluation of pollution control benefits gained through past and current control programs be conducted.

I. OVERVIEW

This first chapter presents a general overview of the state-of-the-art in estimating benefits of air and water pollution control. The material is based on the three papers that follow, as well as other sources referenced at the end of this chapter (Heintz et al., 1976 and Waddell, 1974). References to specific material in the three papers are given, wherever appropriate, to direct the reader to additional information. This chapter is covered under the headings: purpose and scope, conceptual foundations, air quality benefits, and water quality benefits.

A. PURPOSE AND SCOPE

This section sets the scene for subsequent discussion by presenting the background for this study, its purpose and scope, and the plan of work.

1. Background

Nearly everyone is now satisfied that there exists a causal relationship between environmental pollution and certain damages suffered by society. These may take the form of increased incidence and prevalence of disease, diminished recreational experience, decreased property values, reduced crop yields, more frequent maintenance and replacement of exposed materials, and other, less well-identified losses. This being the case, a reduction in pollution levels should bring about a corresponding decrease in these damages and produce a set of benefits equivalent to the difference in damages before and after the reduction took place.

Legislators, planning officials, and other environmental decision makers are frequently faced with the decision of how much to reduce pollutant levels, in the light of the associated direct costs of pollution control and possible secondary economic impacts. In the past, the rationale for these decisions was rather obvious, in that they were often made in response to popular sentiment. However, as economic conditions have changed for the economy as a whole, as well as for certain industries, the costs have become more acutely felt, especially in the wake of the energy crisis. At the same time, the beneficial effects of reduced, or stable, pollution levels were neither obvious, nor easily measured. Clearly, the decision makers would need a more sensitive tool for comparing and trading off the costs and benefits of various levels and types of pollution control.

It was this need that gave birth to increased interest in environmental benefit/cost or tradeoff analysis, including benefit assessment research. Admittedly, this research is an inexact science, primarily because the underlying biological and physical relationships need considerable additional research and because social benefits and costs are diffuse and frequently difficult to quantify, much less to express in monetary terms. Even so, the process of logical and systematic scrutiny inherent in benefit/cost analysis can contribute substantially to the ability of decision makers to improve the social welfare through more efficient allocation of the limited resources of the public treasury.

This potential contribution of tradeoff analysis was apparently recognized by the framers of the National Environmental Policy Act of 1969 (PL 91-190), primarily in Sections 102 and 204. Section 102 calls for the "identification and development of methods and procedures which will ensure that presently unquantified environmental amenities and values may be given appropriate consideration in decision making, along with economic and technical considerations." Section 204 charges the Council on Environmental Quality (CEQ) to gather, analyze, and interpret timely and authoritative information concerning the conditions and trends in the quality of the environment.

In recent years, there have been a number of estimates of the benefits of air and water pollution control. Among the most notable were the reports on air and water pollution by Waddell (1974) and Unger et al. (1974), respectively. More recent estimates are reported in CEQ's annual report, Environmental Quality - 1975. However, there seems to be a widespread skepticism about the validity of available benefit estimates.

With the recent reorganization of the U.S. EPA's Office of Research and Development, the benefits assessment program is being reevaluated. This report should serve as valuable input into the evaluation and re-direction of the benefits research.

2. Purpose and Scope

The purpose of this project is to assit decision makers in U.S. EPA and other Federal agencies by providing a critical review of the current state of the art and future prospects of estimating benefits of air and water pollution control. This should prove valuable in allocating limited pollution control resources; assessing the prospects for further benefits research; and in scoping out a viable benefits research effort.

The specific objectives of this effort are as follows:

- To assess the current state of the art in estimating benefits of air and water pollution control, including validity and accuracy of techniques and data
- To assess the future prospects of benefit estimation
- To identify fruitful areas for additional research.

The scope of this effort can be formulated in terms of the pollutants, benefit categories, affected populations, geographic areas, and time horizon. The benefit categories for air and water pollution are listed below:

Air pollution:

- Human health
- Vegetation
- Materials
- Aesthetics
- Other (animals, ecological risks, etc.)

Water pollution:

- Human health
- Production (municipal, industrial, and agricultural supplies; commercial fisheries and materials)
- Recreation
- Aesthetics and property values

The remainder of this chapter discusses the conceptual foundation of estimating pollution control benefits and summarizes air and water quality benefit discussions as presented in the subsequent chapters.

B. CONCEPTUAL FOUNDATIONS

This section addresses the conceptual foundation of estimating pollution control benefits as presented in the three papers. Detailed references to the papers are provided throughout. The topical headings are: nature and role of benefits, damage functions, valuation of effects, aggregation of results, representation of uncertainties, and conclusions and recommendations.

1. Nature and Role of Benefits

Benefits of controlling air and water pollution arise from gains resulting from improvements in air and water quality. Such gains can be the reduction of damages caused by pollution or the increase in options now feasible because of improved environmental quality. The corresponding economic damages result in "out of pocket" losses by increasing the costs of using air and water, by decreasing their use or activities depending on their use, and by increasing the costs of avoiding or repairing the effects of pollution. A basic concept in benefit evaluation is "willingness to pay," defined as the highest price that individuals would be willing to pay to obtain the improvement in air or water quality resulting from a given pollution control program. Economists prefer to evaluate benefits in monetary terms, because this provides a common measure of all types of benefits and costs.

However, many types of damages are not amenable to quantification in monetary terms, because of their nature and the state-of-the-art of available measurement methods. These difficult-to-measure benefits probably account for a substantial portion of the total value of pollution control to society. This is the case with "psychic" damages, so labeled because they relate to the pleasure or displeasure associated with the use of the environment. Psychic damages include decreased pleasure and increased pain and anxiety from the use of polluted air or water, as well as the loss of non-user values.

Non-user values arise with people who have no immediate plans of making direct use of an environmental amenity, but are nevertheless willing to pay for its preservation for a variety of reasons. In the case of option value, they wish to ensure an option of being able to use it in the future. Vicarious or bequest values describe the benefits experienced by people who would provide these environmental amenities to their heirs or others. Preservation value is associated with the desire to preserve a unique natural resource. Finally, risk aversion refers to the willingness of people to pay for decreasing or averting the risk of a catastrophic or irreversible damage, such as the flooding of arable land or extinction of a biological species. (Heintz, Hershaft, Horak, 1976).

Over time, as the underlying benefit analyses become more reliable, estimates of pollution control benefits should provide for establishment of more efficient environmental policies. However, equity considerations, as well as various political, institutional, and technical issues also enter into the decision making process. A thorough tradeoff analysis would integrate all of these factors.

Other contributions of benefit estimation may be listed as follows (Chapter II pp. 6-8; IV 3-4):

- Enhanced understanding of the problem, the underlying factors, and potential solutions
- Development of an analytical framework for entering inputs from other sources
- Establishment of reasonable environmental quality standards.

Estimation of pollution control benefits ideally should follow the sequence of steps listed below (Heintz et al., 1976; II 53-65):

- Project pollutant emissions on the basis of population levels and economic activity for the area and time period under consideration
- Estimate reduction of pollutant emissions attributable to implementation of given control policy

- Estimate improvements in environmental quality associated with stipulated reduction of emissions
- Estimate reduction in adverse effects associated with improvement in environmental quality
- Estimate regional benefits (in monetary terms if possible) of reductions in adverse effects and other considerations
- Extrapolate and aggregate regional benefit estimates across all relevant regions and time periods of interest to obtain national estimates.

The first two steps involve the projection of a suitable economic scenario and evaluation of the cost-effectiveness of various administrative and technological pollution control fixes. The third step requires the use of complex models of the diffusion and assimilation of specific pollutants within their respective media. The remaining steps rely on (1) the development of damage functions and (2) economic benefit analysis. These two topics form the basis of this report and receive closer scrutiny in the pages that follow.

2. Damage Functions

Damage functions provide a quantitative expression of the relationship between exposure to specific pollutants. The type and extent of the associated effect can then be estimated based on a target population, or "population at risk". Despite their crucial role in the formulation of benefits of pollution control, damage functions have been treated lightly in the three papers that follow (Chapters II, III and IV), because the essence of damage functions is more physical and biological than economic. Thus, most of the material presented in this section is abstracted from Hershaft *et al*. (1976).

A typical S-shaped damage function, showing the damage corresponding to a given exposure to a specific pollutant, is presented in Figure I-1. The ordinate may represent either the number of individuals affected or severity of effect. The abscissa indicates the dosage in terms of time at a given ambient concentration, or in terms of ambient concentration for a fixed period of time. The lower portion of the curve suggests that, up to a certain exposure value, known as a "threshold level", no damage is observed, while the upper portion indicates that there exists a damage saturation level (e.g., total destruction of the target population) beyond which increased exposure levels do not produce additional damage. The middle, quasi-linear portion is very useful in that any data points here can be readily interpolated, and the frequent assumption about linearity of a damage function is most valid in this sector.

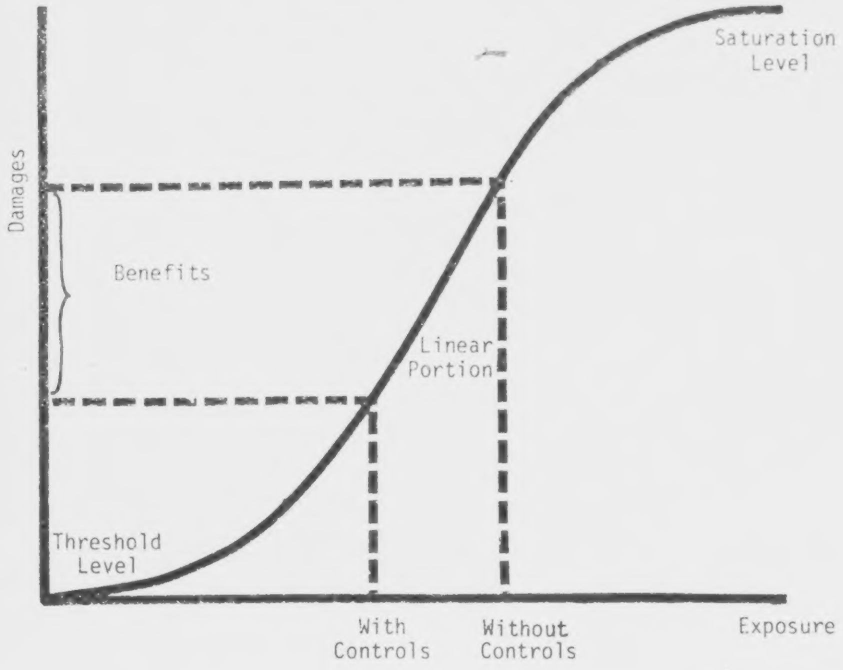


Figure I-1. Hypothetical Damage Function

Exposure is typically measured in terms of ambient concentration levels and their duration and it may be expressed as "dosage" or "dose". Dosage is the integral of the time and ambient concentration to which the subject has been exposed, whereas dose represents that portion of the dosage that has been actually instrumental in producing the observed damage. The damage can become manifest in a number of ways and can be expressed in either physical and biological, behavioral response, or economic terms. If the effect is physical or biological, the resultant relationship is known as a physical or biological damage function, or a dose-effect function. In an economic damage function, on the other hand, the effect is expressed in monetary terms. Economic damage functions can be developed by assigning dollar values to the effects of a physical or biological damage function, or by direct correlation of economic damages with ambient pollutant levels.

In reporting a damage function, one needs to specify the pollutant (or surrogate), the dose rate, the effect, and the "population at risk". Dose rate, or the rate at which ambient concentration varies with time, has a major influence on the nature and severity of the resultant effect. For example, long-term exposure to relatively low concentrations of air pollutants may result in manifestations of chronic disease, characterized by extended duration of development, delayed detection, and long prevalence. Short-term exposure to high concentration levels, on the other hand, may produce acute symptoms, characterized by quick response and ready detection, as well as chronic cumulative, or delayed effects.

Specification of the population at risk involves the characterization of the nature and magnitude of the exposed population. Damage functions, when extrapolated on the basis of population at risk, serve to define the total damages produced by a given level of exposure by multiplying the corresponding unit damage (e.g., increased mortality) for the specified population at risk (e.g., white males over 65) by the total number of units within this population. Detailed population characteristics also permit investigators to adjust their results to reflect the influence of various intrinsic (e.g., age, race, sex) and extrinsic (e.g., general health, occupation, income, and education) variables in assessing the specific effects of air pollutants (e.g., increased incidence of lung cancer). Finally, population-at-risk information can provide useful guidance for allocating pollution control resources by identifying areas with particularly susceptible populations exposed to relatively hazardous levels of pollutants. (Takacs and Shea, 1975).

The data required to develop physical or biological damage functions are obtained primarily through epidemiological, field, clinical, toxicological, or other laboratory investigations. The first approach involves the comparative examination of the effects of pollutants on selected segments of population exposed to different levels of pollution, in order to deduce the nature and magnitude of the likely effect. Field observations represent a similar approach to assessment of effects on animals, vegetation, and materials, and they are characterized by similar analytical techniques and concerns. Clinical studies are concerned with the effects of exposure on human subjects. Toxicological investigations involve deliberate administration of controlled doses of pollutants to animal, and occasionally, human subjects, and observation of the resulting effects. Laboratory studies represent essentially the same approach for determining effects of pollutants on plants and materials.

The three principal techniques for analyzing the relationship between exposure and effect indices in epidemiological studies are known as cross tabulation, multivariate regression, and non-parametric or distribution-free analysis. Cross tabulation is the simplest of the three. Multivariate regression provides a rapid indication of the degree of association between a large number of independent and dependent variables and is readily programmable for computer operation. However, its validity is heavily contingent on a fairly precise *a priori* definition of the relationship between each independent and the dependent variables and on precise measurement of the independent variables. Thus, this technique is especially vulnerable to the poor precision in measurement and reporting of air pollution levels, for example, for a given segment of population. Non-parametric analysis, on the other hand, is free of these assumptions, but requires laborious data reduction for each of the many pairs of independent and dependent variables and interposition of expert judgment at each step of the process.

In the development of damage functions on the basis of epidemiological or field studies, it is important, albeit complex, to isolate or control the influence of cofactors and covariates. The former may be defined as factors that act in concert with the independent variables (e.g., relative humidity or cigarette smoking and pollutant level). Covariates, on the other hand, may be thought of as factors that vary jointly with the principal dependent variable. The interference of cofactors and covariates with results of the analysis can be reduced by holding them constant or with the aid of statistical techniques. When this cannot be done, it is frequently assumed that the distribution of these factors in the target population is sufficiently uniform to avoid vitiating the basic conclusions.

Finally, it should be noted that epidemiological and field studies and observations can only indicate an association between exposure to pollution and the observed effect, suggesting the existence of a causal relationship. Such a relationship can then be tested by clinical, toxicological and laboratory studies.

3. Valuation of Effects

Estimation of economic benefits of a given improvement in environmental quality involves either conversion of the associated reduction of adverse physical and biological effects into monetary terms, or direct determination of the user's willingness to pay for the improvement. The three common methods to estimating benefits of pollution control are:

- Alternative cost
- Opportunity cost
- Willingness to pay.

The alternative cost method is employed most frequently, because of its rapid applicability and avoidance of complex economic analysis. This involves development of a damage function, leading to estimation of the total damages corresponding to exposure of the target population over a specified period. Because there is no provision for substitution or any other mitigative adjustment by the target population, the damage estimate may be excessive. (III 16).

Opportunity cost, on the other hand, is estimated on the basis of the cost of substitution and other adjustment opportunities open to the target population. This formulation presumes that ownership to the environmental good is held by the target population, which is then entitled to trade it away for a substitute good.

Finally, the willingness-to-pay method is based on the determination of how much the affected population is willing to pay to avoid the particular environmental degradation. Here, the title is presumed to be vested in the perpetrators of environmental degradation, rather than the target population. (III 17).

An alternative formulation of approaches to estimation of pollution control benefits is as follows (IV 5-6):

- Market prices, if a market for these goods and services exists and the additional output does not affect price significantly
- Simulated market prices (especially useful for estimation of recreation and aesthetic benefits)
- Changes in net income of producers for consumers, if outcome represents an intermediate good (useful for production benefits)
- Cost of most likely alternatives for obtaining same objective.

In spite of general reliance on simulated markets, some market price data are also useful in estimation of benefits. These data need to be germane, relatively free of price imperfections, and adjusted to long-term expected levels. Technological externalities should be included and monetary externalities should be excluded in estimating these benefits. Finally, the annual changes in benefit streams should be identified for the various benefit categories. (IV 5-9).

Estimation of benefits on the basis of willingness to pay entails the intermediate steps of estimating changes in user behavior associated with anticipated reductions in the adverse effect and the marginal willingness to pay associated with these changes. Changes in user behavior reflect the user's perception of environmental quality. Moreover, they are affected by local socioeconomic conditions. (IV 10-11).

The benefits associated with a change in environmental quality are defined by the area under the demand curve over the applicable range, but, since environmental amenities are generally not bought and sold in the marketplace, there may not be any direct way of estimating the shape of the demand curve by conventional econometric techniques. Instead, discreet market values may need to be inferred from individual responses to changes in environmental quality. The techniques for drawing these inferences are known as market demand analysis, net productivity, net factor income, travel cost studies, land value studies, and personal interviews. (II 15-16).

Another representation of the relationship between changes in environmental quality and the user's utility or welfare is known as "consumer's surplus". This is defined as the difference between what an individual is willing to pay and the market price. .Determination of consumer's surplus can be affected by an alternative formulation of the problem. (III 9-10).

An important element in estimation of pollution control benefits is the aversion of grave environmental risks brought about by pollution. The value of risk aversion can be measured through observation of individual behavior, or through lottery games. The first method is preferred, because it is more realistic, permits construction and testing of behavior models, and provides for application of opportunity cost or willingness-to-pay formulations. (III 19-21).

In closing this discussion, it is important to bear in mind that the data required to implement these valuation steps are frequently difficult to obtain and that some of the economic concepts, such as the value of human life, or non-user benefits, have not been adequately defined. Thus, judgmental estimates need to be frequently substituted for hard data and a balance must be struck between the desirable and available data and techniques. In such cases, it is very important to state explicitly all assumptions, the reasons for their selection, and the implications of choosing different assumptions. Otherwise, the estimate can easily be misleading and discredit the entire benefit estimation process. (II 5-8).

Usefulness of benefit estimates is governed by their adherence to the following provisions (II 9-11):

- Consistent terminology
- Clearly defined pollutant levels
- Clearly identified pollutants and sources
- Appropriate degree of detail
- Clearly defined relationships between pollutant levels and human values.

The term "costs" should apply to pollution control resources; "damages" should refer to the total loss to society due to a polluted environment; "benefits" should represent the gains realized by society from a given improvement in environmental quality. Similarly, the quality levels being compared should be already defined as those "with" and "without" controls, rather than those "before" and "after" applications of controls, to avoid time-related complications, such as inflation. (II 9-10).

The pertinent pollutants and their sources should be clearly identified with the environmental improvement sought, to avoid gaps and overlaps in the estimation procedure. Moreover, policy decisions should be based primarily on marginal benefits associated with efects of the particular decision, rather than on average or total benefits that would accrue in the absence of pollution. (II 9-10).

Benefit estimates corresponding to a given environmental improvement should be expressed in monetary terms and should be based on individual behavior and preference. Empirical measures and techniques should be appropriate to the specified theoretical model and available data. Finally, these estimates should reflect the regional and temporal variations in both economic and environmental variables. (II 9-11, 34-35).

The type and degree of geographic, temporal, and economic detail should be tailored to the specific needs of the user. For example, only a rough estimate may be needed to make an initial decision, with more detailed estimates being provided for more refined future decisions. (II 11).

4. Aggregation of Results

Most benefit estimation studies address a specific geographic location, group of pollutants, population at risk, and time period. Extension of these results to the national level and some future time frame requires the aggregation of the regional estimates and projection of a number of variables, including ambient levels, populations at risk, personal incomes, and costs of damages. In aggregating over several variables, it is important to specify the order in which the variables are being aggregated. (III 24-28).

The benefit categories for which the data are collected are often dictated by availability of information sources and analytical expediency, rather than the needs for a uniform and self-consistent framework. Consequently, different studies evaluate damages that are not necessarily additive, or even comparable, and careful interpretive techniques must be applied to the results of such studies to prevent gross overlaps or omissions of damage estimates. Moreover, in aggregating such fractional results, it has not been possible to reflect the potential impacts of changes in individual components on one another, nor the impact of the general adjustments of the economy and the resulting reduction in damages. (Heintz et al., 1976).

Aggregation of benefit estimates entails a tradeoff of detailed information about form and structure in return for treatability and ease of comprehension. Attempts to apply aggregated national estimates to local pollution control decisions can introduce substantial errors, because the information lost in the aggregation process cannot be recovered. In principle, national estimates may be developed directly, rather than by aggregation of local studies. (III 24-28). However, additional research in this area is necessary.

Overlaps and gaps between categories of benefits may arise when two types of effects (e.g., health effects and property values, in the case of air pollution, and recreation benefits and property values, in the case of water pollution) are estimated by different methods which may count the same benefit component twice or fail to capture certain other components. It is important, therefore, to attempt removal of the excess count and to inpute a value for the missing component. Another problem is the inconsistency in quality of estimates for different benefits categories. (II 20-23; IV 13-14).

If the benefits of interest accrue over a number of years, then it may be useful to compute the present value of the total stream of benefits with the aid of an appropriate discount rate and time horizon. This approach becomes less effective when the projected effects extend over a very long time period that spans several generations (intergenerational effects), because of the large reduction factor. For example, using a discount rate of 5 percent, the current benefit of an effect occurring 200 years hence is reduced by a factor of

6×10^{-4}. In such cases, the consideration of intergenerational equity should outweigh that of intertemporal efficiency. Another problem in computing the present value of the stream of benefits is the differential growth rates. (II 23-24; IV 13-14).

5. Representation of Uncertainties

Uncertainties about benefit estimates arise from errors in the four intermediate steps of the estimation process:

- Specification
- Measurement
- Valuation
- Aggregation.

Errors of aggregation are associated with attempts to extrapolate national values from regional estimates or future values from current or past estimates. They arise from geographic and temporal variability of user behavior and market conditions. Errors of valuation are due to the difficulty of assigning monetary values to certain physical, biological, aesthetic, or psychic effects. (III 22-23).

Errors of specification include any type of error in specifying the functional form of the relationship under study or in accounting for important variables. A particularly common and grave error of specification is committed in attempting to extrapolate a complete functional relationship from a few data points that are barely adequate to characterize a small portion of the curve. Even if one were willing to make an assumption about the overall shape of the function, there is frequently no way of knowing which portion is represented by these data points. (Hershaft et al., 1976).

Errors of measurement may be incurred in the course of the following steps of the benefit estimation process:

- Location of monitoring station and subjects

- Sampling and analysis

- Averaging and aggregation of ambient pollutant levels
- Determination of effect
- Impact of covariates
- Characterization of population at risk.

If the errors of measurement of the independent variables are relatively small, occur at random, and follow a normal, or Gaussian distribution about the mean value of each variable, then the total error of all the independent variables can be computed by standard statistical techniques. However, this is seldom the case, because measurement of such independent variables as pollutant level, meteorological conditions, and socioeconomic characteristics is subject to errors that are both large and biased. The advantages of this statistical approach include an opportunity to incorporate more information in the reported results and the assignment of a probability to the various outcomes. (Hershaft et al., 1976; II 24-26; III 23-24).

Envelopes characterizing errors and uncertainties of benefit estimates can be also obtained by more practical means, including:

- Replicating a specific study using new data or methods
- Providing ranges of values of the more important variables
- Combining results of several studies
- Applying "best" and "worst" case assumptions.

Replication and data manipulation are essentially empirical techniques of determining the errors and corresponding confidence bands. Combining the results of several studies is a rare and uncertain opportunity, in light of the great variety of conditions and populations that often characterize the different efforts. Application of "best" and "worst" case assumptions is more an argumentative than a statistical technique. The lower boundary, or best case, is established by attributing all reasonable portions of the effect to any plausible cofactors and covariates and associating only the residual effects with pollutant exposure. The upper boundary, or worst case, is determined by inverting this procedure and assuming a minimal impact of other variables. (Hershaft et al., 1976).

6. Conclusions and Recommendations

A number of major conclusions emerge from the discussion of conceptual foundations of estimating pollution control benefits:

- Estimates of pollution control benefits would potentially be very useful to decision makers (II 46)
- However, available estimates do not adequately reflect the state of the art (II 48)
- The conceptual basis provided by economic theory for benefit estimation is adequate in most respects and far ahead of the corresponding empirical effort (II 46)
- Nevertheless, a number of studies have employed conceptual models that are inappropriate to the problem at hand or the available data
- A number of studies have failed to list explicitly critical assumptions or to express adequately uncertainty in the results
- National benefit estimates are based on regional studies which are frequently inadequate in number and/or quality
- Damage functions underlying benefit estimates are frequently based on insufficient data and/or inadequate characterization of exposure and effects (II 27-30)
- Benefits assessment research has been accorded a relatively low priority by the U.S. Environmental Protection Agency, perhaps because of skepticism about its value, or the public health and ecosystems focus of environmental legislation (III 40-41)
- Past U.S. EPA research strategy has been characterized by short-term, piecemeal studies which are not conducive to the accumulation of a consistent and comprehensive data base useful in decision making (III 41-42)

- Some aspects of benefit estimation are subject to value and equity judgments, rather than application of economic theory (II 47-48; IV 13-15)
    - relative merits of different distributions of benefits among population groups
    - adverse consequences of present actions on future generations

Recommendations for improving general estimation of benefits are as follows:

- Reassess funding for benefits estimation research in light of its potential utility to decision-making process and the uncertainties permeating other, currently funded national assessment programs (III 41-42)
- Develop and implement a comprehensive national plan for closely coordinated regional benefit studies that is well grounded in economic theory and provides for consistent aggregation and expression of the uncertainty of all estimates (III 42)
- Develop and implement a comprehensive program of *ex post* evaluation of pollution control benefits gained through past and current control resources (II 53)
- Convene a group of experts every few years to develop comprehensive estimates of national benefits of pollution control (II 52)
- Employ scientists from other disciplines in planning and implementing benefits estimation studies (IV 25).

C. AIR QUALITY BENEFITS

This section presents an overview of the discussion on benefits of air pollution control contained primarily in Chapter III. Specific references to this chapter are provided wherever appropriate. The topics covered are: current estimates, health benefits, aesthetic benefits, vegetation and materials benefits, and recommendations.

1. Current Estimates

The latest estimates of national air pollution damages have been compiled by Heintz *et al*. (1976). These are equivalent to benefits that would accrue annually from reduction of air pollution to threshold levels. Table I-1 summarizes the benefit estimates for the four major classes of benefits, in terms of best estimates and corresponding ranges. The latter were derived largely through a proportional representation of the ranges quoted by Waddell (1974).

Table I-1. Estimated National Damages of Air Pollution for 1973 ($ billion)

Damage Category	Best Estimate	Range Low	 High
Health	5.7	2.0	9.4
Aesthetic	9.7	5.7	13.7
Vegetation	2.9	1.0	9.6
Materials	1.9	0.8	2.7
Total	20.2	9.5	35.4

Source: Heintz *et al*., 1976

To gain a proper perspective of these estimates, it is important to recognize that they do not reflect all of the potential damages from air pollution. There are a number of categories of potential damages for which estimates are not available. The most important of these is the threat to preservation of the natural environment, including unique ecosystems and species. But, even within the categories for which estimates are available, the existing monetary measures tend to understate the total damages. For example, the estimated health damages reflect the direct and indirect costs of illness, such as health care costs and lost earnings, but do not reflect the value of lost leisure time or the psychic costs of illness and death.

In combining estimates from different classes of damages, care has been taken to minimize double counting. For example, studies of the differences in residental property values associated with differences in air pollution reflect primarily the aesthetic and soiling effects, rather than health effects. This is based on the argument that the aesthetic effects are experienced directly in everyday life, whereas health effects are mostly long-term, and are not distinguishable by the general population from other causes of illness. Although improved education may be altering people's awareness of the health effects of air pollution, it is not likely that this has been significantly reflected in past property values, on which these benefit estimates have been based.

The damage estimates presented here are based on the interpretation of the results of numerous studies of varying scope, methodology, and data quality. The availability and reliability of information from these studies is indicated in Table I-2. It will be noted that effects data are most available for effects of SO_x, oxidants, and particulates and for the damage categories of human health and vegetation.

Table I-2. Availability and Reliability of Information on Air Pollution Damages

Damage Categories	NO_x	Oxidants	SO_x	CO	HC's	Particulates	Other
Human Health	SF	SF	IG	SG	SF	IG	IF
Aesthetics	U	SF	IG	U	U	IF	U
Vegetation	IF	IG	IF	SG	SF	SF	SF
Materials	SF	IF	IG	SP	SP	SG	U

Source: Heintz _et al._, 1976

Availability	Reliability
A - ample	E - excellent
I - insufficient	G - good
S - scarce	F - fair
U - unavailable	P - poor

2. Health Benefits

The key consideration in estimation of health benefits of air pollution control is the valuation of human life. This can be accomplished by the Thaler-Rosen or the productivity method. The former estimates the average value of human life as somewhat in excess of $200,000 on the basis of individual preference for higher wages versus more risky occupations. The problem with this method lies in the fact that willingness to pay for preservation of human life rises steeply with proximity of death. (II 17-18).

The productivity, or human capital method values each life at the present value of the expected stream of the individual's future earnings. The difficulties here are the conversion of a probabilistic estimate into a specific stream of earnings and the failure to value lives of people who receive no compensation for their labor (e.g., housewives, children, retirees, volunteers). It should be noted also that there is no logical connection between value of future earnings and willingness to pay. (II 18-19).

The household production function is an analytical framework that can be applied in estimating health benefits of pollution control. This theory views the consumer as combining market purchased goods and his own resources to produce a given state of health. The major advantage of this method is that it provides for dealing with the inadequacies of previous methods, such as failure to take into account the value of leisure and uncompensated time as well as individual adjustment to pollution. (III 31-32).

3. Aesthetic Benefits

Estimation of aesthetic benefits of air pollution control encompasses a number of the concepts discussed in Section B. This is illustrated in Chapter III Attachment, which discusses a case study involving the impact of air pollution on the outdoor recreational market in San Bernardino, California. These concepts may be described as (III 46-54):

- Multidimensional heterogeneity
- Cost of market participation
- Institutional and temporal constraints.

The first term refers to the fact that outdoor recreational sites exhibit substantial differences in a number of dimensions (e.g., size, topography, vegetation, facilities, congestion, accessibility). The second concept deals with the relatively high cost of participating in the outdoor recreation market due to travel requirements, search for a suitable site, and purchase of special implements (e.g., hiking boots and backpacks). Finally, the market is subject to a number of controls exercised by public institutions, such as health and safety regulations and restrictions on attendance, as well as constraints on the time schedule available for recreation. (III 49-53).

Another aspect of aesthetic benefits is reflected in property values. An improved method of obtaining an aggregated national estimate of property value changes has been developed. This method does not assume that the same set of weights applied to each locale, time period, and household, nor does it ignore the manner of distribution. Moreover, it is soundly grounded in economic theory and is capable of capturing several elusive features of the market. (III 29-30).

4. Vegetation and Materials Benefits

Estimates of air pollution damages to agricultural crops have focused on the physical measures of damage and have ignored the effect of the resulting changes in output on the unit price. Yet, models of agricultural markets that are capable of capturing these price effects are generally available and should be applied to the estimation of crop damages (III 36).

Past studies of production damages of air pollution have focused on materials damages and have neglected the involvement of these inputs in the production process. It appears desirable, in this connection, to assess the effects of air pollution on labor supply and productivity. The findings should be transferable to other cases of occupational exposure. (III 33).

Past attempts to construct indices of air pollution control benefits failed, because they viewed benefit changes as nearly synonymous with changes in ambient concentrations, and social valuations were based almost exclusively on air quality standards. This representation could be improved by viewing ambient quality as a factor of production, e.g., changes in morbidity characteristics associated with certain pollutant levels. (III 34).

Results of interviews to ascertain individual preferences are frequently biased by the interviewees' anticipation of how their responses will be used. Nevertheless, differences in willingness to pay for various pollution levels may provide a valid representation of the marginal willingness to pay, which is of primary importance in policy decisions. Moreover, techniques have been developed for eliciting truthful responses about preference orderings. (III 35-36).

5. Recommendations

The following research projects are recommended to improve estimation of air pollution control benefits:

- Apply the household production function framework to obtain health benefits of pollution control (III 31-32)
- Conduct research on value of human life along two approaches (II 50):
    - determination of willingness to pay for small changes in probability of death
    - determination of the value implicit in public decisions involving public safety
- Assess effects of air pollution on labor supply and productivity (III 32-33)
- Prepare improved estimates of benefits derived from available property value studies and conduct new studies (II 52; III 29-30)
- Apply available models of agricultural markets to estimation of crop damages (III 36)
- Investigate improved methods of assessing willingness to pay through interviews (III 35-36).

Benefit estimation would also gain from the following recommendations designed to improve development of air pollution damage functions (Hershaft et al., 1976).

- Determine how well air quality measurements at the monitoring station represent the ambient quality affecting the population at risk
- Determine the impact of mobility and shielding of the subjects on their exposure

- Develop a composite index of exposure representing both prevailing and extreme values
- Define current air quality monitoring requirements for potential future damage studies
- Assess and improve the accuracy and reliability of various methods for determining morbidity
- Develop a method for determining changes in life expectancy due to exposure to air pollutants
- Provide uniform guidance for designing studies of the effects of air pollutants on vegetation
- Conduct studies on the following effects of air pollutants:
  - specific effects of NO_2 and nitrates
  - specific effects of different types of sulfates
  - chronic effects of low-level exposures to specific pollutants
  - carcinogenic, teratogenic, and mutagenic effects of specific pollutants
  - effect of oxidants on yields of major crops
  - effects on paints, cement, rubber, plastics, and wood
  - effects on climate and local weather conditions.

D. WATER QUALITY BENEFITS

This section presents an overview of the discussion on benefits of water pollution control contained primarily in Chapter IV. Again, specific references to this chapter are provided wherever appropriate. The topics covered are: current estimates, recreation benefits, aesthetic and ecological benefits, health benefits, production benefits, and conclusions and recommendations.

1. Current Estimates

The latest estimates of national water pollution damages have been compiled by Heintz *et al*. (1976). These are equivalent to benefits that would accrue annually from reduction of water pollution to "threshold" levels. Table I-3 summarizes these estimates for four major classes of damages, in terms of best estimates and the corresponding ranges. The latter reflect the substantial uncertainty associated with these estimates.

Table I-3. Estimated National Damages of Water Pollution for 1973 ($ billions)

Damage Category	Best Estimate	Range Low	Range High
Outdoor Recreation	6.3	2.5	12.6
Aesthetic and Ecological	1.5	0.6	2.8
Health	0.6	0.3	1.0
Production (including municipal, industrial, agricultural supplies, commercial fisheries, and materials damage)	1.7	1.1	2.3
Total	10.1	4.5	18.7

Source: Heintz *et al*., 1976

Since the largest damages are in the recreational, aesthetic, and ecological categories, the total estimates strongly reflect the uncertainties inherent in the currently available data and techniques for estimating the monetary value of these uses of water. The estimation of recreation damages depends upon understanding the behavior of recreationists when confronted with a complex set of choices concerning types of recreation, travel, sites, and the quality of the recreational experience. In determining aesthetic and ecological damages, it is necessary to consider the value which individuals place on viewing or preserving waterways of high quality.

A broad spectrum of studies have been reviewed to obtain information on water pollution control damages. Table I-4 reports on the availability and reliability of the information contained in these studies.

Table I-4. Availability and Reliability of Information on Water Pollution Damages

Pollutant	Outdoor Recreation	Aesthetic and Ecological	Health	Production Losses
Acidity	SF	U	U	SP
BOD	IF	SP	U	IF
Coliform Bacteria	SF	U	SP	SP
Floating Solids	IF	U	U	SP
Hardness	U	U	U	IP
Nutrients	SP	U	U	SP
Odor	U	U	U	U
Oil	SP	SP	U	SP
Pesticides	U	U	U	U
Sediment	IF	IF	U	IF
Temperature	IF	SP	U	SP
TDS and Salinity	U	U	U	IF
TSS and Turbidity	SF	U	U	SP
Toxic Metals	SP	U	U	SP
General Pollution	AF	SP	SP	IF

Source: Heintz et al., 1976

Availability:	Reliability:
A - ample	E - excellent
I - insufficient	G - good
S - scarce	F - fair
U - unavailable	P - poor

2. Recreational Benefits

Estimates of recreational benefits are based largely on studies of the behavior of recreationists faced with changing water quality. The analysis attempts to predict how recreational patterns and the resulting values gained by recreationists would be affected by changes in water quality parameters. Unfortunately, damage functions relating these changes are very sketchy. (IV 11, 20).

Most national benefit estimates are based on a few partial studies of local recreational patterns. This presents two sources of uncertainty. First, there is considerable variation in the relationship between water quality and consumer behavior from one geographic location to another. Second, local studies cannot account for the large number of options open to the recreationist, i.e., how deterioration of water quality at one site affects his behavior at other sites. (IV 19-20).

Two other points are worth noting. Most studies consider only two pollution levels: the current and the one meeting water quality standards. Instead, a range of pollution levels should be examined to determine that level where marginal costs become equal to marginal benefits. In addition to the usual efficiency grounds, improvement of water quality for recreation could be justified on other grounds, such as compensation to those who can not afford to recreate elsewhere, preservation of future options, and national pride. (IV 20-21).

Water pollution affects recreation by reducing the quality of the recreational experience, by causing the consumer to recreate less often, and by causing him to incur higher travel costs to enjoy substitute sites. The last of these components is measured most readily. However, the use of travel costs for this purpose is susceptible to the following complications (IV 21-22):

- Unusual income elasticities
- Impact on travel of highway construction, crowding, and gasoline prices
- Inertia in recreational preference
- Transfer of recreation from a more distant, but more desirable site to a closer site, as a result of pollution of the distant site.

Two conceptual models estimating national recreational benefits by aggregation of site and situation-specific results have been developed. The first examines the conceptual links between quality, quantity, and price of the recreational experience. The second model demonstrates the usefulness of a "reduction in travel cost" construct and specifies data requirements. (IV 23-24, Attachment A and B).

3. Aesthetic Benefits

The state of the art in estimating aesthetic and ecological benefits is even more limited than that for estimating the recreational benefits. Effect of water quality on aesthetic and ecological concerns and the resultant consumer behavior modification are difficult to measure, because they are not well reflected in market transactions. Consequently, such estimates are based on personal interviews which seek to determine the value placed by consumers on these concerns. It is widely suspected that the interviewees are attempting to affect the results of the interview by their responses, i.e., that there is a substantial disparity between what they say they would do and what they would actually do. Although psychologists and other behavioral scientists have been able to cope with this problem, their expertise has not been brought to bear on these studies. (IV 25).

It is difficult to draw general conclusions from current empirical work, because it focuses on high-quality, unique environmental services, rather than medium or low-quality services. Moreover, there is some question whether estimates of option values should be incorporated in benefit estimates, in light of their softness and consequent weakening of the validity of total benefit estimates. (IV 26-27).

Changes in property values have been employed to estimate aesthetic benefits of water pollution control. These changes have been regarded with some suspicion, because it was felt that they reflect a redistribution of wealth, rather than a net addition to national productivity or efficiency benefits. On the other hand, property value changes may reflect an actualized option demand which should be included as an efficiency benefit, because it indicates that buyers seek to insure a continued future supply of environmental services for private use. (IV 27-28).

The use of property value changes to estimate the aesthetic benefits suffers from several limitations. One is the difficulty of avoiding double counting of benefits with those in the recreational category. Moreover, there is a general scarcity of property value data which can be adequately linked to water quality levels. (IV 28).

4. Health and Production Benefits

Improvements in estimating health benefits hinge on a more precise definition of the relationship between water quality and the incidence of waterborne diseases, such as hepatitis, gastroenteritis, salmonellosis, and typhoid. The key problem in quantifying health benefits is how best to deal with uncertain, long-term relationships, such as the presence and effects of carcinogens. Also, determination of the value of human life is complicated by the fact that society may be willing to expand the effective willingness to pay of an individual beyond his future earnings. (IV 16-17).

Production benefits arise from water pollution control, because water is a direct input to many production activities. These activities may be divided to include municipal, industrial, and agricultural water supplies, commercial fishing, and materials damage categories. Available estimates of these benefits have been made with the aid of the alternative cost, or technical coefficient approach. This approach is based on estimating the additional cost incurred in these production activities, because of water pollution and assumes that the reduction in such costs would be proportional to the reduction in pollution levels. The costs addressed include treatment of water before use, maintenance and repair of equipment, and decreased production. (Heintz et al., 1976).

Production benefit estimates obtained under this approach suffer from the failure to consider substitutions and other market adjustments made by the producer to mitigate the effects of pollution on production activities. Another problem lies in the assumption that marginal costs of treating man-made pollutants are equivalent to the prorated portion of the average cost of treating both man-made and natural pollutants. This may lead to over estimation of the benefits due to control of man-made pollution. A problem in the estimation of agricultural damages on the basis of crop prices is due to distortions brought about by price support for farm products and other institutional manipulations. (IV 18-19).

5. Conclusions and Recommendations

The following conclusions are drawn from the preceding discussion:

- The theoretical framework for estimation of water pollution control benefits is far more advanced than the corresponding empirical work (IV 29)
- Estimates of national benefits of consumption losses (e.g., recreation, aesthetics) are much less firm than those for production losses and prospects for improvement of this situation are not good (IV 29)

- Reduction of travel costs offers a potential for assessing recreational benefits at a higher level of aggregation (IV 30-31)

The following actions are recommended to improve estimation of water pollution control benefits:

- Prepare more complete and valid behavioral response functions, including demand curves for specific recreation sites (II 50; IV 30)
- Establish a long-term "behavioral monitoring system" that would measure simultaneously basic economic and ecological factors, objective and perceived water quality parameters, recreational activity, and property values (IV 31-32)
- Apply the new models to the estimation of recreational benefits (IV 23-24, Attachments A and B)
- Improve interview techniques for estimating aesthetic benefits by seeking help from behavioral scientists (III 35-36; IV 25)
- Prepare improved damage functions defining the relationship between water quality and the incidence of waterborne diseases (IV 16)
- Prepare improved estimates of the value of human life (II 50; IV 17-18).

REFERENCES

Heintz, H. T., Jr., A. Hershaft, and G. C. Horak, National Damages of Air and Water Pollution Control, U.S. Environmental Protection Agency (Contract No. 68-01-2821), September 1976.

Hershaft, A., et al., Critical Review of Air Pollution Dose-Effect Functions, Council on Environmental Quality (Contract No. 5-AC012), March 1976.

Takacs, I., and G. B. Shea, Human Population at Risk to Various Levels of Air Pollutants, U.S. Environmental Protection Agency (Contract No. 68-01-2820), February 1975.

Unger, S. G., et al., National Estimates of Water Quality Benefits, U.S. Environmental Protection Agency (Contract No. 68-01-2997), November 1974.

Waddell, T. E., The Economic Damages of Air Pollution, U.S. Environmental Protection Agency, EPA-600/5-74-012, May 1974.

II. BENEFITS OF POLLUTION CONTROL

A. Myrick Freeman, III
Bowdoin College

A. INTRODUCTION

The issues to be discussed in this paper can be stated most concisely in the form of four questions. First, "would national estimates of benefits from controlling air and water pollution be useful to public officials and others concerned with evaluating pollution control policy alternatives?" Second, "is it possible to use the available economic theory, empirical techniques, and data base to make national estimates which can be supported on logical and scientific grounds?" The third and fourth questions presuppose generally affirmative answers to the first two questions. The third is, "do available estimates of national pollution control benefits adequately reflect the present state of the art?" And finally, "what can be done to produce better estimates of national benefits?"

It is perhaps misleading to present the "possible" and "useful" questions as if they were entirely separable. The way the questions are asked implies the possibility of a simple yes or no answer. But what is "possible" depends upon the resources and effort devoted to the exercise of measurement. And this in turn depends upon the expected usefulness or utility of the information being sought. The importance of the question and the likelihood that more information will improve the decision determine the value of additional information such as estimates of national benefits. Policy makers should seek more information on national benefits as long as the marginal value of the improved benefit measure exceeds the marginal resource cost of obtaining it.

Section B continues the discussion of the possibilities and usefulness of national estimates of benefits in somewhat more detail. While the questions posed at the outset focus primarily on national estimates of benefits, it is not possible to provide complete answers without some reference to the problems and possibilities for estimating benefits for individual pollution control projects, river basins, and air sheds. Generally, national estimates of benefits involve some form of extrapolation or aggregation based on parameters and relationships derived from more narrowly focused studies of a particular region or pollution control project. Of necessity then, the evaluation of the possibility of national estimates must consider the theory and practice of benefit estimation in general. This is the topic of Section C.

Secion D discusses three conceptual problems in benefit estimation. The representation of uncertainty through the use of probabilistic statements and confidence intervals is recommended. The willingness to pay versus forgone earning approaches for valuing human life are discussed. The latter seems to be unsatisfactory on both conceptual and empirical grounds. In the absence of definitive estimates of willingness to pay, it is suggested that decision makers experiment with explicit assumptions or value judgments about the value of life. The problem of temporal aggregation of benefit streams over time is discussed in terms of the principle of discounting and present value. The problem of intergenerational effects seems to raise questions which are probably fundamentally ethical in nature.

Section E reviews a number of problems in the empirical techniques and data for benefit estimation. Topics covered include overlap and gaps among categories, the effect of multi-collinearity on measurement and prediction, the biases due to misspecification of variables, and the problem of adequately summarizing air pollution data collected over a substantial interval of time. The section concludes with a review of the adequacy of available data and technique for dealing with air pollution data, property value effects, health effects of air pollution, recreation benefits, and benefits from increased industrial productivity and reduced vegetation and materials damages.

Section F discusses the process of developing national estimates of benefits from the building blocks of region-specific, pollutant-specific, and effect-specific studies. Specific suggestions are made for estimating national mortality changes from cross-section regressions of mortality versus air pollution and aggregating the information contained in property value studies for individual cities. Also the problem of national recreation benefit estimation is discussed.

Section G makes a number of specific recommendations for improving estimation techniques and for additional research. The final section is devoted to some concluding observations.

B. POSSIBILITY AND USEFULNESS OF NATIONAL BENEFIT ESTIMATES

The feasibility, or possibility, and usefulness of national benefit estimates are the cardinal issues in this critical assessment. They are examined here along with the corollary issue of information content.

1. On Possibility

Since the nation is simply the aggregation of its regions, however defined (as air sheds, river basins, or political subdivisions), the possibility of developing national benefit estimates hinges on our ability to make estimates of particular classes of benefits in a specific region. Data from particular regions constitute the building blocks of national estimates. If nothing meaningful can be said about the benefits of a specific pollution control plan in a particular region, then no meaningful aggregation to the national level is possible.

Estimating benefits is essentially an economic process. The discipline of economics is the source of the concept of benefits; and the definition of benefits and the conceptual basis of their measurement are derived from a type of economic model. Yet benefit estimates must be built upon a non-economic base. For example, health benefits due to air pollution control must be built upon scientific knowledge of the relationship between pollutant concentrations and human health. In recreation and fisheries, benefits stemming from water pollution control may require knowledge of the relationship between pollutant levels and biological productivity. It is clear that lack of information in some non-economic areas severely limits our ability to make estimates of economic benefits. But aside from acknowledging the existence of this problem, no more will be said here. Rather our attention will be devoted to the economic aspects of benefit estimation.

Suppose the Administrator of EPA wished to know the magnitude of the benefits to be expected from a particular pollution control program. If asked, could the economist specify what economic theory and models he would use, what data he would like to have, and what empirical techniques he would apply to the data to obtain benefit estimates? The answer is a qualified "yes". After completing a review of the available techniques for measuring the benefits of water pollution control for the U.S. Environmental Protection Agency, I concluded: "The economic theory and analytical techniques for evaluating benefits for most types of uses are relatively well developed. At least, this is the case for the most significant classes of user benefits (Freeman, 1975)."

The qualifications are threefold. First, some of the data the economist would like to have is non-economic, e.g. dose-response functions, physical damage functions, and these data may not be available. Second, in the economic realm there are still major unresolved theoretical and empirical issues with respect to valuing human life and health effects and various forms of non-user benefits such as aesthetics and option value. And third, the kind of economic data that the economist would like to have are seldom already available or easily obtainable at modest cost. Major data gathering efforts would be required to obtain the primary economic data called for by the correct theoretical models. Lacking data in the ideal form, the economist must resort to second best theoretical constructs and utilize sophisticated econometric techniques in an attempt to wrest some modicum of useful information from the limited and imperfect body of data.

Because of the several qualifications, successful benefit estimation, either at the local or national level, requires striking a balance between rigorous theory and correct empirical technique on the one hand and pragmatism and informed judgment on the other. Where there are gaps in knowledge concerning key parameters and relationships, and where it is not possible to devote resources to closing these gaps within the scope of the existing research effort, it may be appropriate to make an informed assumption about the unknown relationship in order to push the analysis through to its conclusion.

This procedure is valid provided that: the assumption is made explicitly and openly; the basis for choosing the assumed value rather than some alternative is fully discussed; and the implications of alternative assumptions are made clear through sensitivity analysis on the outcome or carrying confidence limits through to the final outcome. The necessity for making assumptions may stem from ignorance concerning empirical relationships, e.g., dose-response relationships for air pollutants, or inherent problems of evaluation, e.g., the valuation of human life. These issues are discussed in more detail in a recent National Academy of Sciences Report to U.S. EPA (National Academy of Sciences, July 1975, esp. Chapter 6, and Appendix 8).

If the practice of benefit estimation were highly developed, the estimation of benefits at the national level would proceed simply by estimating benefits separately for each region or basin, and then summing them over the nation as a whole. But this is clearly not the case. The real question for policy analysts is how far can one depart from the ideal of rigorous and theoretically precise estimation for all sites, moving toward the bastardized but pragmatic process of first approximation, reasonable assumption, and judgment, and still obtain estimates which are considered reasonable and useful for the questions at hand. It is hard to provide an answer to this question in the abstract. As was indicated in the introduction, this depends in part on the resources available to support adequate investigation, and in part on the kinds of policy questions being posed and the value of additional information.

2. On Usefulness

Useful to whom? To officials responsible for environmental policy planning and decision making. Benefit estimates are useful if they provide an improved information base for environmental decision making. Achieving air and water pollution control objectives established by Congress will involve massive expenditures both through the public sector and private sectors. There is a potential for substantial gains through more effective utilization of the resources devoted to pollution control via the judicious use of benefit-cost analysis in evaluating policy alternatives. It must be emphasized that benefit-cost analysis as we use the term is not a rule for decision making. Environmental decision makers may have other objectives besides the simple economic efficiency objective which underlies the benefit-cost rule. For example decision makers may be concerned with equity considerations, intergenerational effects, or risk aversion, none of which can be incorporated in a simple equation for decision making purposes. Also, it is seldom feasible to provide the full range of complete and accurate benefit and cost information to the decision maker which would be required for the unqualified acceptance of the benefit cost rule. Rather, questions of uncertainty and information gaps are likely to exist.

Benefit-cost analysis can be very valuable as a framework and a set of procedures to help organize available information. In this way, benefit cost analysis does not dictate choices, nor does it replace the ultimate authority and responsibility of decision makers. Rather, it is a tool for organizing and expressing certain kinds of information on the range of alternative courses of action. It is in the context of this framework for arraying information that the usefulness of national benefit estimates must be assessed.

Although the major thrust of Federal pollution control policies has already been established by the U.S. Congress, there are still many important decisions to be made. Also, looming problems may force reconsideration of major elements of existing policies. Most of these issues involve either an implicit or explicit weighing of benefits versus costs. For example, U.S. EPA and U.S. Congress are weighing proposals to change the emissions standards and/or the timetable for compliance for automobiles. National Secondary Air Quality Standards require at least an implicit balancing of benefits versus costs. And to defend effluents standards based upon the best practical treatment and best available treatment criteria against legal challenge, U.S. EPA will have to have information on the benefits to be expected from the standards they are setting. There are two things to note from this sampling of future U.S. EPA and Congressional decision problems. First, while decision makers may have other objectives besides economic efficiency, it is clear that economic considerations, broadly defined, will play a significant role in the decision making process. And second, each of these decision problems is national in scope and requires national estimates of benefits and costs.

This discussion has established the potential value of national estimates of benefits. But it must be recognized that, under some circumstances, benefit estimates can be damaging rather than useful. If estimates succumb to the fault of misplaced concreteness, if they contain conceptual or analytical errors, if they do not make explicit the key assumptions and value judgments involved, and of they do not express their inherent lack of accuracy through some device such as confidence limits, the estimates may do more harm tnan good. They may mislead policy makers in key decisions. And as their faults and weaknesses become known, they may discredit the whole process of benefit estimation and policy analysis.

Finally, even if benefit information does not become an input into a decision process, the exercise in quantification and measurement that benefit estimates require may be itself of educational value to researchers and policy makers. The exercise requires that investigators gain a better understanding of the nature of different pollutants, the paths that pollutants follow in reaching people, and the variety of ways in which pollutants affect the uses that people make of their air and water environments. Even if the exercise does not bear fruit in the form of monetary estimates of benefits, the insights gained and the pieces of information developed may be of value themselves.

3. Information Content

A major factor influencing the usefulness of estimates of national benefits is the nature and quantity of specific information contained in the estimates. A statement that "air pollution costs $20 billion per year" contains almost no useful information. To be useful for policy purposes, any statement about national benefits must abide by the following minimum provisions:

- Consistent terminology
- Well-defined pollutant levels
- Identity of pollutants
- Sources of pollutants.

The statement must be consistent in its use of the terms "benefit," "cost," and "damage". The benefits of pollution control are measured by comparing the present situation characterized by a known degree of pollution with some specified hypothetical alternative for which pollution has been reduced or eliminated. Benefits are the gain associated with reduced pollution. The statement of benefits should make clear whether the measure refers to total benefits for some non-marginal change in pollution levels or marginal benefits for some small change in pollutant levels. The statement should also indicate whether benefits are defined per capita or in the aggregate.

Damages represent the mirror image of benefits measuring what is lost in moving from some hypothetical clean state to the existing level of pollution. Pollution control benefits are the same as reduced damages. The term "costs" should be used only to refer to resources absorbed in the process of controlling or reducing pollution. Its use to denote damages should be avoided.

The statement concerning benefits must clearly specify the alternative pollution levels being compared, both the present dirty level and the hypothetical cleaner alternative. Is the polluted state defined as conditions in 1975, or for example, 1973 (when pollutant levels and adverse effects may have been either higher or lower)? Specifying the reference year is also important for determining the price level for expressing dollar measures of benefits (e.g., in 1973 dollars), and for specifying values for other socioeconomic variables which might influence the analysis of benefits.

Four choices for the hypothetical alternative seem to present themselves:

- Zero ambient concentrations of pollutants (this may be unrealistic where there are natural sources of the pollutant in question)
- Zero manmade emissions -- that is, ambient levels equal to background levels from natural sources
- Ambient levels above background levels but below all known thresholds (this alternative would be difficult to implement, because of the considerable controversy over threshold levels)
- Ambient levels at promulgated air or water quality standards (this is the most useful alternative for evaluating present pollution control policies).

The estimates should make clear which pollutant or group of pollutants is being referred to. Where the benefit estimates are provided for a group of pollutants (e.g., all air pollutants), the statement should include a disaggregation or breakdown by individual pollutants, unless the pollutants within the group act synergistically, so that such a separation of effects is not analytically possible. Benefit estimates for a group of pollutants may also be useful where the group is controlled jointly.

For each benefit estimate, the statement should indicate whether all sources are included, or, for example, only mobile sources. Where the purpose of the benefit estimate is to evaluate a pollution control policy, benefit estimates should exclude potential benefits associated with non-controlled sources. For example, pollution control benefits associated with the control of non-point water pollution sources should not be included in an estimate of benefits associated with municipal and industrial point-source control program.

The kind of information which should be contained in a statement of benefits also depends upon the nature of the policy question for which the estimate was made. For example, in the early stages of the development of a pollution control policy, the most important question might be one of priorities, i.e., which classes of pollutants should be controlled most quickly. For this purpose, very rough order-of-magnitude estimates of total benefits by pollutant would be very helpful. Later, as control plans are developed, marginal benefits, and benefits by source would be required.

The main thrust of Federal policy since 1970 has been away from regionally differentiated air and water quality standards and toward uniform national ambient standards and national standards for emission levels and control technologies. This evolution of a nationally standardized set of policies has increased the importance of national estimates of benefits. The process of setting national primary air quality standards would be aided by national estimates of marginal benefits by pollutant. And the development of pollution control strategies requires national estimates of benefits by source.

In conclusion, the type of policy question being considered governs the nature and detail of the benefit information required. Planning on a regional basis requires estimates of regional benefits and costs. National policy choices require national estimates. And since the building blocks of valid national estimates of benefits are regional studies of specific pollutants, once these studies are done, their aggregation to the national level is relatively simple. And the effort to get better national estimates will stimulate research on obtaining better building blocks.

C. THE THEORY OF BENEFITS

This section reviews the conceptual basis of benefits and some empirical techniques for estimating benefits. These topics have been treated extensively in other studies for the U.S. EPA (Haveman and Weisbrod, 1975; Freeman, 1975).

1. Efficiency and Equity

By definition, benefits are desirable consequences. But we require some criterion for defining and measuring desirability. Welfare economics has conventionally distinguished between efficiency and equity as criteria for judging alternative economic states. Efficiency refers to the total availability of those goods and services valued by individuals without reference to whom they accrue. Equity refers to the pattern of the distribution of available goods and services among individuals. What constitutes equity or fairness in the distribution of goods and services cannot be defined objectively. Equity involves value judgments about the relative "deservingness" of individuals. For this reason, economic analysis focuses on the efficiency criterion on the argument that it is objective or value-free.

The efficiency criterion requires a rule for assigning values or prices to goods and services so that they can be added up to determine a total value. The price system of a market economy provides the necessary set of relative values, provided markets are competitive, there are not externalities, etc. These prices would appear to constitute the set of values necessary for the implementation of an objective efficiency criterion, and to validate the dichotomy between efficiency and equity. But this is not the case. And this is one of the insoluble problems in the analysis of benefits. The price set is not independent of the initial distribution of wealth among individuals in the economy. Thus, if the price set is taken to be valid as a measure of values, this implies that the underlying distribution of wealth which produced those values is acceptable in equity terms. A redistribution of wealth will lead to a different set of relative prices. And an allocation of resources judged efficient under the initial distribution would likely be inefficient under the new distribution. Which measure of efficiency is to be preferred depends upon one's value judgment about the equity of the two wealth distributions. There is no way around this problem, so it is typically ignored in the practical business of applied welfare analysis. In other words, the existing distribution of wealth and its resulting set of relative prices are assumed to be acceptable in equity terms.

2. Measurement of Benefits

Benefits are defined in terms of the increase in welfare or utility of consumers stemming from some action to control pollution. Benefits can accrue to consumers either directly in the form of increases in the availability of utility conveying goods and services (e.g., improved health, better visibility, improved recreation opportunities), or indirectly through increases in production efficiency (for example, due to reduced defensive expenditures, reduced materials damages, etc.). Pollution control involves the use of limited resources which have opportunity costs measured in dollars. This means that the benefits must also be defined and measured in commensurate dollar terms. Furthermore these dollar measures must be firmly rooted in and based upon individual preferences and values.

Economic theory shows that there are two ways in which monetary measures of welfare changes can be derived from individuals' preferences. The two approaches differ only in their definition of the status quo ante from which the welfare change is measured. One approach, termed the willingness-to-pay approach, asks how much an individual would be willing to pay to receive an extra quantity of the utility-conveying good or service, rather than do without. It assumes that the individual does not have a legal property right in additional units of the good, and therefore must give up control over other goods and services (pay) in order to receive more of this good. The other approach, termed the compensation approach, asks how much the individual would have to be compensated in money terms in order to induce him to give up or forego some quantity of the good. This approach assumes that the individual has a legal property right in the good, and could only be induced to give up the good if the amount of the compensation conveyed an equivalent amount of utility. (National Academy of Sciences, 1974, pp. 400-404).

The two approaches lead to quantitatively different answers only if the marginal utility of income to the individual changes as the individual moves from one position to another. If the marginal utility of income is diminishing, the compensation approach will lead to a higher measure of benefits than the willingness-to-pay approach. Where the marginal utility of income is constant, or can be assumed to be approximately constant (for example, where the changes are very small relative to total income), the two approaches can be taken to be equivalent.

The benefit associated with a particular pollution control action is defined as the sum of the willingness-to-pay of all individuals affected directly or indirectly by that action. Analytically, willingness-to-pay implies the existence of a demand curve for the consequences of that action. Benefits are equal to the area under that demand curve, properly defined. Benefit estimation involves an attempt, either indirectly or directly, to determine the shape of that demand curve. This definition of benefits meets two important criteria for an adequate framework for benefit estimation: the definition is firmly rooted in the economic theory of individual preferences and values and it leads to objectively determined monetary measures of welfare or benefit.

3. The Estimation Process

Although the definition of benefits focuses on the existence of a demand curve, its application in the realm of pollution control must also deal with two other problems associated with the "production" of benefits. The process of producing pollution control benefits has three distinct stages:

- Improvement in environmental quality through reduction of pollutant discharges
- Increase in uses of environmental amenities due to their improved quality
- Increase in willingness to pay due to changes in use of environmental amenities.

A reduction in the quantities of polluting substances being discharged into the air or water leads to an improvement in various measures of air or water quality. Modeling this transformation process between changes in residual flows and changes in ambient pollutant levels is outside of the realm of economics. Yet it is a task which must be done before the benefits of pollution control projects can be estimated.

Changes in ambient pollutant levels lead to changes in the ways in which individuals make use of the air or water, that is, changes in the level and composition of the stream of environmental services yielded by the air and water bodies. For example, changes in ambient air pollutant levels may lead to changes in morbidity and mortality rates. Understanding these relationships is an essential part of the estimation process. This might be termed the measurement process to distinguish it from the process of valuation which constitutes the next stage.

Changes in uses or service flows have their counterpart in changes in aggregate willingness to pay for uses of the environment. Determining the relationship between changes in quality and changes in use is only a partly economic problem. Determining the relationship between use and value is strictly the economist's domain, since here the economic concepts of demand and value are central to the analysis.

The benefit associated with a change in air or water quality has been defined as equal to the area under the demand curve for the environmental service over the relevant range. But, since environmental services are generally not bought and sold in organized markets, there may not be any direct way of estimating the shape of this demand curve by applying normal econometric techniques to observed market data. The basic methodology used for estimating benefits involves techniques for inferring values of environmental services where market processes have failed to reveal these values directly. Thus, benefit estimation often involves a kind of detective work for piecing together the clues about the values individuals place on these goods as they respond to other economic signals.

There are several different situations where the way in which environmental services enter economic processes permits estimation of willingness to pay for improvements in environmental quality by indirect means. In an earlier study for the U.S. EPA (Freeman, 1975), I analyzed the economic theory underlying several types of cases, where environmental services were inputs in production, where environmental services were complementary to other goods and consumption, where environmental services were perfect substitutes for other goods in consumption, and where environmental quality levels were characteristics of fixed assets such as land. In that study, I also reviewed a number of techniques, e.g., market demand analysis, net productivity, net factor income, Clawson-Knetsch travel costs studies, land value studies, and interview techniques, in light of the earlier discussion of economic theory. Each of these techniques (except the interview technique) relies on some model of individual behavior and some set of assumptions about the nature of the benefits being analyzed to deduce a relationship between the unobserved values individuals assign to environmental benefits and related observable market signals.

D. CONCEPTUAL PROBLEMS IN BENEFIT ESTIMATION

There are a number of conceptual issues that need to be addressed in the process of benefit estimation. Among the most pressing of these are valuation of human life, handling of overlaps and gaps, aggregation of the stream of benefits over time, and expressing uncertainty of the results.

1. Valuation of Life

A major category of potential air pollution control benefits is improved health and reduced mortality. Assuming that these benefits can be measured or quantified, how can monetary values be attached to them? Some might say that putting a price on human life is insensitive, crass, and even inhuman. But this point of view must be rejected on practical grounds because both individuals in their day to day actions and governments in their decisions about social policy do in fact make tradeoffs between changes in probability of death and other goods with money values; and these tradeoffs imply money price tags being attached to life.

Individuals in a variety of actions act as if their preference functions included probability of death or life expectancy. They make decisions which involve reductions in life expectancy in return for increases in income or other goods and services, revealing, thereby, that they perceive themselves to be better off having made these choices. Individuals who continue to smoke despite the Surgeon General's warnings could be viewed as trading off the consumer surplus attached to smoking against the now widely publicized reduction in life expectancy. Individuals also make implicit tradeoffs between life expectancy and reduced travel time when they chose a mode of travel, for example private autos vs. bus. The individual willingness to pay framework has been developed by Schelling (1965), Mishan (1971), Zeckhauser (1974), and Thaler and Rosen (1975). Thaler and Rosen in particular have developed a framework for estimating the individual tradeoff between probability of death and higher wages in more risky occupations; and they have tentatively estimated the implied value of human life to be between $176,000 and $260,000 per life. Although this estimate cannot be taken as definitive, it does provide a point of reference for further work in the area and for assumptions and value judgments as described below. (National Academy of Sciences, 1975, Chapter 6).

What should be the basis for determining these values? The conceptually correct basis for valuation is individual willingness to pay. But this willingness to pay must be defined and evaluated in the correct context. The question is not how much would one be willing to pay to avoid certain death tomorrow. Rather, for the relevant policy questions, e.g., health effects of pollution control, safety and accident prevention, the precise identity of the people affected is not known. Safety regulations reduce the probability that any one individual in a population at risk will be killed during a given period of time. It is this kind of question that Thaler and Rosen investigated. Reductions in air pollution, for example, are likely to affect the whole probability distribution of the date of death for affected individuals. One measure of this change in the probability distribution would be to define the change in life expectancy. The changes in higher moments of the probability distribution might also be important, especially for things such as accident prevention. (Freeman, 1975).

The other major approach to valuation in the literature is the so-called productivity or human capital approach. It values each life lost at the present value of the expected stream of future earnings for that individual had that individual's death been avoided. There are several serious weaknesses and limitations to this approach. First, it assumes that it is possible to identify ex ante those whose lives will be saved. Second, it does not take into account the probabilistic nature of death and death avoidance in the health and safety problems. Third, there is no logical connection between earnings and willingness to pay, especially in the probabilistic framework. And finally, this measure places no value on the lives of those who are not working for reasons of age, sex, or other factors.

While lost earnings can be readily calculated, that approach is conceptually unsatisfactory. In contrast, the conceptually valid willingness to pay for changes in life expectancy approach is appealing, but it is only now being elaborated and subjected to empirical testing. In the absence of generally accepted empirical estimates of individual willingness to pay, it is still useful for the researcher to proceed beyond the measurement stage in benefit estimation by applying assumed unit values to predicted changes in mortality and morbidity. In this way, the analyst can examine the implications of alternative unit values for aggregate benefit estimates, and for benefit cost comparisons. (National Academy of Sciences, 1974).

However, if such assumptions are made, several points must be kept in mind. First, the assumptions should be made openly and explicitly. This is not the case with estimates of air pollution health benefits provided by Lave and Seskin (1970) who fail to explain the implications of their assumptions about health values. They used earlier data from Dorothy Rice on direct and indirect costs of mortality and morbidity. The indirect cost of mortality was defined as forgone earnings due to early death.

Second, researchers should provide an examination of the sensitivity of final benefit estimates to changes in assumed unit values. For example, final figures could be presented in the format of high and low range and "best estimate". A third consideration is that, whatever assumptions are made about unit values, it would be helpful for readers of these studies to have the assumptions related to other work. For example, if a researcher chose to use a value substantially below that used in other work which might be familiar to the reader, the researcher should offer some reason for making that assumption. Finally, where assumed values are used in making resource allocation decisions, such as allocating medical services, or setting standards for air pollution or toxic chemicals, there is much to be said for using a consistent set of values across the whole range of public decisions.

While this discussion has been carried out in the context of valuing human life, most of the same points can be made concerning assumed unit values for other difficult to price environmental services, for example recreation user days. The Water Resources Council guidelines call for agencies to apply unit values to predicted recreation days in calculating benefits of water resource development. While there are problems in the application of particular unit values (Freeman, 1975), there can be no objection to the practice in principle, provided that the considerations outlined above are recognized. Assumed unit values can be utilized provided they are based upon a review of other analytical and empirical studies designed to measure unit values of recreation under similar circumstances.

2. Overlaps and Gaps

One major problem area in estimating benefits is the possibility of either overlap among or gaps between categories of benefits as estimated by presently used techniques. This kind of problem can arise where two kinds of effects associated with the same pollutant are estimated separately. For example, do estimates of health effects and property value changes associated with particulates involve some double counting of particulate damages, or are there additional effects not captured by either measure? Although definitive answers to this question cannot be given here, the discussion will show that it should be possible to determine when such gaps and overlaps exist. It should also be possible to make some judgment as to the significance and likely direction of any biases in the estimated total benefit figures. And this should be useful in deriving confidence limits or high and low bounds surrounding best estimates of total benefits.

Consider the case of air pollution where health benefits are measured by mortality rate studies and aesthetic benefits are measured through property value differentials. The justification for measuring two classes of benefits separately and adding them to obtain aggregate national benefits is that only those effects of air pollution which are perceived by individuals can influence property values, and that people have for the most part been ignorant of the effects of air pollution on their health and life expectancy.

But one can feel somewhat uneasy about this simple resolution of the problem. Some kinds of short term health problems (eye irritation, shortness of breath) may be directly perceived as being caused by air pollution. And there has been a substantial increase in the information (and misinformation) available to the general public about long term health effects and relative air pollution levels around urban areas. Thus, perceptions of health effects may be influencing property value differentials and leading to the possibility of double counting. To gain a better understanding of the problem, it is necessary to consider in more detail exactly what is captured by each of the two approaches to measurement.

It will be helpful to develop a system of classification for different types of effects. Aesthetic effects are defined to include odor and taste, reduced visibility, soiling, damage to external paints, etc. By definition, aesthetic effects are perceived by individuals. Impacts on health constitute the other broad class of effects. For purposes of this discussion, we need not distinguish between morbidity and mortality effects. But we can, at the conceptual level, distinguish between those health effects which are perceived by individuals and those of which they are ignorant. The former are likely to be primarily clinical manifestations of short term exposures at relatively high levels. Finally, it is necessary to distinguish between those effects which are caused by pollution exposure at home and those which are caused by the person's exposure as he travels around the urban air shed, to work, for shopping, for recreation, etc. These "away from home" effects are independent of the individual's place of residence.

This classification scheme is displayed schematically in Figure II-1. There are six subsets of effects classified by aesthetics, health--perceived, health--unperceived, and in all cases further divided between home and away. Property value studies can only capture those effects associated with the home which are perceived. Health benefits derived from mortality and morbidity studies capture both home and away effects and both perceived and unperceived health effects.

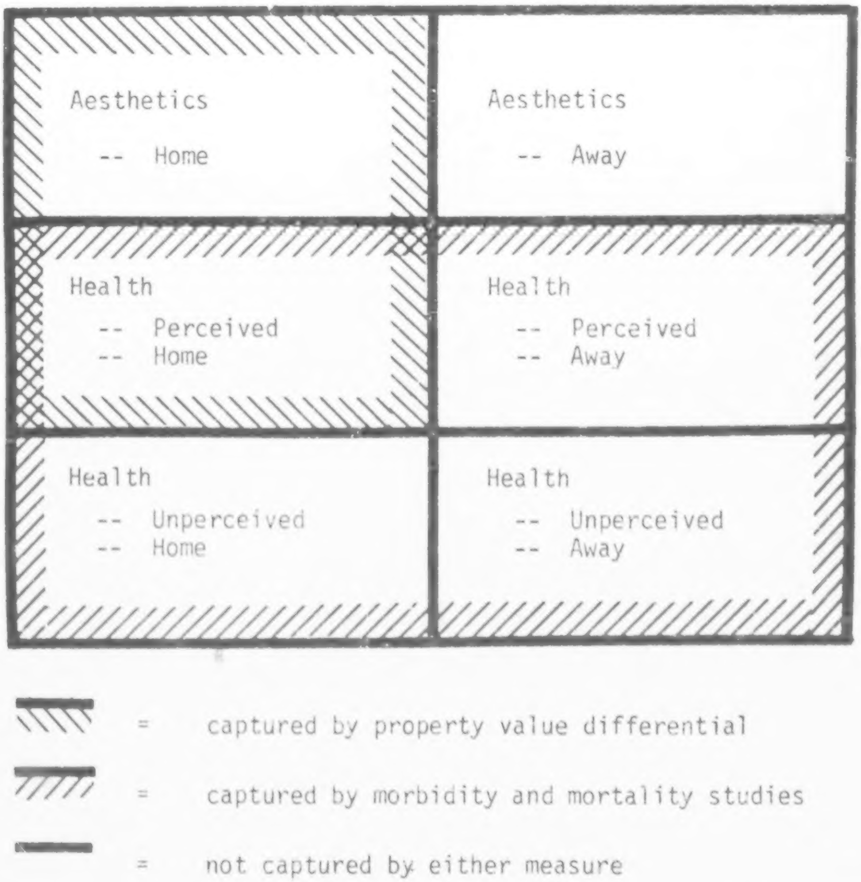

Aesthetics
-- Home
Aesthetics
-- Away
Health
-- Perceived
-- Home
Health
-- Perceived
-- Away
Health
-- Unperceived
-- Home
Health
-- Unperceived
-- Away
= captured by property value differential
= captured by morbidity and mortality studies
= not captured by either measure

Figure II-1. Classification Scheme for Capture of Effects

The figure illustrates both an overlap and a gap. Perceived health effects at home are captured by both the property value and health effects approaches. But aesthetics associated with away from home exposures are not captured by either measure. Whether the addition of property value and health effect benefits results in an overestimate or an underestimate depends upon the relative size of the doublecounted and omitted categories. Nothing can be said about this question on *a priori* grounds.

There is a similar kind of problem in the case of water pollution where recreation benefits and property value benefits are both being estimated. Property value measures capture both the value of easy access to the improved water based recreation opportunities and other non-recreation aesthetic benefits (e.g., wildlife appreciation, elimination of odor and unsightly flotsam). In estimating recreation benefits the double counting problem can be avoided by identifying recreation participants as either from abutting property or from away, and counting for benefit purposes only anticipation by those from away. This can easily be accomplished if benefits are being estimated for a particular site, for example by the Clawson-Knetsch method. However, if benefits are being estimated at the national level from a national recreation participation survey, it may not be possible to identify that part of participation attributable to property owners using abutting water bodies. Thus, adding property value benefits to those estimated from a national participation model will involve some degree of double counting.

3. Temporal Aggregation

For many pollution control programs, benefits accrue over many years. We have discussed benefits under the assumption that an estimate is for a given year. But for some circumstances, we may wish to examine the whole time stream of benefits. This would be the case, for example, if the pollution control program involved capital costs now to produce a stream of benefits over the future. Each year's benefit is temporally distinct and not comparable or additive to benefits accruing in other years or with costs without some system of weights. The appropriate weighting system is derived from the discount rate.

There are two issues: the choice of a discount rate and the time horizon. I see no reason to depart from the accepted practices of project analysis on either of these issues, at least for benefits and costs accruing over the next, say, fifty years. (Kneese and Herfindahl, 1974).

The issues are more complex when we consider effects extending over very long periods of time, for example between generations. Discounting with the normal discount rate can reduce even catastrophic distant future effects to nominal present values. For example, with a relatively low discount rate of 5%, the benefit of avoiding some number of deaths 200 years in the future is reduced by a factor of 0.0006. On the basis of conventional discounting, the benefits of preventing some future catastrophe, for example the effects of possible destruction of the ozone layer, may seem less than the present costs of preventing the effect. It appears that in cases of this sort, the major consideration is not intertemporal efficiency in resource allocation, but rather intergenerational equity in the distribution of welfare. Hence, it should not be surprising that decision rules based on the efficiency criterion should appear to give unreasonable results. This is a problem which is beginning to receive attention in the literature. But as yet, there are no generally accepted answers.

4. Uncertainty of Results

A major problem area is the development of a framework and a language for conveying the uncertainty about the accuracy of benefit estimates. Even the most careful estimate of benefits contains inaccuracies because of errors in the measurement of variables and errors in the statistical estimation of relationships. In addition, it may be necessary for the analyst to make assumptions regarding unknown parameters, relationships, and values. The uncertainty inherent in these errors must be expressed somehow in the final benefit figure. The most appealing way of dealing with these problems is through the use of probabilities to quantify uncertainties. This is straightforward in theory because probability is a natural language for describing uncertain situations. (National Academy of Sciences, 1974, Appendix 8).

Most people are accustomed to using probability informally as a language for describing uncertainty. Weather forecasts are stated in terms of probability of rain. And expectations concerning elections and sporting events are often expressed in terms of odds or probabilities. The same concepts may be used to describe uncertainties related to benefit estimates. Probability theory provides an unambiguous and logically consistent language to reason about uncertainty. In fact, a forceful argument can be made that any logical process for reasoning about uncertainty is equivalent to probability theory.

The same people who use probability naturally in informal situations may be extremely reluctant to use the same ideas in important decision situations. To some extent the problem is one of measurement. Many people are accustomed to viewing probabilities as exact numbers based on objective evidence, for example, as deduced from physical symmetry or observed frequencies from large number experiments. They are uncomfortable with the idea of using subjective probabilities as a language for expressing their judgment on a matter where the available information is limited.

Consider the air pollution/human health relationship. If we had a large body of statistical data on the incidence of mortality over a range of known air pollution exposures, it would be relatively straightforward to assign a probability to a given individual's dying as the result of exposure to that air pollutant. But, if estimates of benefits are desired before this type of data is available, or if those data are very difficult to obtain because of cost, measurement problems, etc., then the analyst must resort to informed judgment and logical reasoning. Judgment must be extrapolated from other information, for example, animal tests, or a review of several less than perfectly successful attempts to measure the desired relationship.

Once the basic assumption has been accepted that probability assignments are not "objective" but represent judgments, that they can summarize information or a state of mind, rather than being physically measurable, then the probability theory for expressing these judgments in a consistent manner is relatively straightforward. For example, what is frequently called the "best guess estimate" can be interpreted as an expected value or mean of the subjective probability distribution. High and low values should be expressed in terms of confidence limits. Where the final estimate is derived from several variables, each with their own estimated degrees of error or uncertainty, the uncertainty surrounding the final estimate is a compound of the component uncertainties. And probability theory provides a logical framework for determining the overall degree of uncertainty.

To those who might argue that the assignment of probability should be rejected because it is subjective, the response is that the present approach to determining best guesses and high and low bounds is also subjective. And often, the method of deriving best guesses and high and low bounds from the underlying data are not consistent from one part of the study to the next. Probability is a language for dealing with subjective estimates in a consistent and logical manner; and, it is one which can be interpreted consistently by others.

E. TECHNICAL PROBLEMS IN BENEFIT ESTIMATION

In addition to the conceptual issues discussed in the preceding section, there are a number of more technical problems that need to be resolved. These include pollution measures, exposure measures, and multicollinearity.

1. Measures of Pollution

A major problem in estimating benefits due to air pollution arises because of systematic errors in the use of aggregate or average measures of the air pollution variable. Consider, for example, the cross section mortality studies of Lave and Seskin which use SMSA's as the sample unit. Assume that there is some single valued measure of the air pollution exposure of an individual. Further, assume that the "true" relationship between this pollution measure and the mortality rate is known. This is portrayed by the solid line in Figure II-2.

Air pollution measures are typically taken at one centrally located monitoring station in the smaller SMSAs, whereas the larger SMSAs may have networks of monitoring stations. In the latter case, pollution measures are some average of readings at the several stations. Assume that for a "dirty" city the air pollution reading at the downtown station is $0\text{-}P_4$. Because some portion of the population lives in suburban areas quite far from the downtown monitoring station, and some portion of the suburban population does not regularly travel to the downtown area, $0\text{-}P_4$ is an overestimate of the true average pollution exposure of this urban population. Assume that the true measure is $0\text{-}P_3$. Reference to the true pollution-mortality relationship shows that this dirty city would have mortality rate of $0\text{-}M_3$. The observed pollution-mortality data would be plotted as point A in Figure II-2.

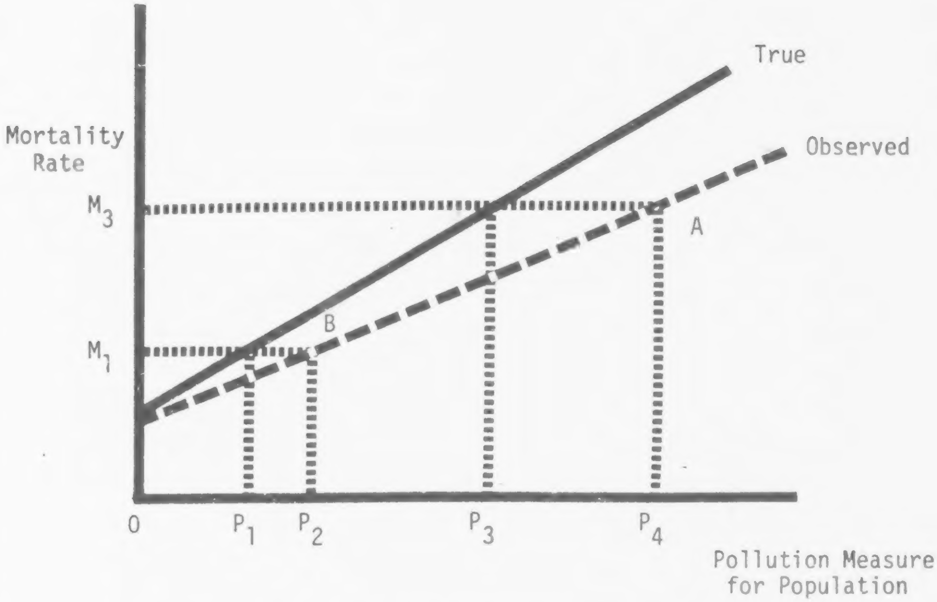


Figure II-2. True and Observed Relationships Between Pollution Measure and Mortality Rate

In a relatively "clean" city, there will also be a divergence between recorded and actual pollution exposures. However, the divergence will be much smaller, since the difference between the "clean" suburbs and "almost clean" downtown area will be much smaller. If 0-P_2 is the recorded pollution measure for the clean city, the clean city observation would be point B in Figure II-2. It can be seen that a regression line fitted to the recorded data would lead to an underestimate of the regression coefficient relating pollution to mortality.

However, while the estimate of the regression coefficient is biased by the error in the pollution measure, if the regression equation is used to predict changes in mortality conditional upon changes in pollution, the regression equation will give "true" predictions. Consider a pollution control program which is expected to reduce recorded pollution in the dirty cities from 0-P_4 to 0-P_2. The regression equation predicts a reduction in mortality of 0-M_3 to 0-M_1.

The pollution control program will actually reduce true exposure from $0\text{-}P_3$ to $0\text{-}P_1$. And the true reduction in mortality will be just that predicted by the regression equation.

Similar problems might arise for mortality or morbidity studies based upon a sample of individuals, if the pollution variable is measured by some proxy. For example, suppose each individual's exposure was taken to be a function of pollution levels at his residence. Then, the recorded pollution measure would understate true exposure for those individuals living in the "clean" part of the city and spending some part of the working day in the "dirty" part of the city. Similarly, for those living in the dirtiest part of the city, the recorded pollution measure is likely to overstate true exposure. By a line of reasoning similar to that developed through Figure II-2, it can be shown that this divergence between recorded and true exposure measures will lead to an underestimate of the slope of the regression line relating exposure to morbidity or mortality. However, unlike the preceding case, the biased regression equation will not provide correct predictions. Rather, the regression equation will underpredict reductions in mortality or morbidity associated with reductions in pollution exposure.

2. Pattern of Exposure

One of the problems in doing research on dose-response relationships or epidemiological studies of the air pollution-mortality relationship is a choice of a time dimension for the air pollution variable. The air pollution level at any particular point in an urban area is an instantaneous variable which fluctuates over time. The true exposure of an individual located at that point is measured by a trace of the time path of that instantaneous variable over the relevant time period. The published data on air pollution levels which are used to generate exposure variables for empirical research involve various approaches to summarizing this instantaneous time path. Inevitably these summaries, such as the annual mean, lose information.

Also, at least in part because of measurement methods, averages are struck over shorter time periods, for example the 24-hour average for particulates, and 8-hour and 1-hour averages for other pollutants. These shorter averages can also provide a basis for summary measures of exposure. For example, Lave and Seskin used the lowest 24-hour average recorded during a year as one measure of long term exposure. No one or two of these measures completely represent the true exposure of any individual. Empirical research is hampered by this inability to accurately characterize exposure over long periods of time.

An alternative approach to summarizing recorded air pollution data may lead to more accurate characterizations of exposure. The suggested approach is based upon the assumption that the instantaneous air pollution reading can be treated as a stochastic variable. For a city with given emissions patterns, meteorological conditions, and location of monitoring stations, the instantaneous air pollution reading can be viewed as being drawn from a probability distribution. That probability distribution has a mean, variance, and other higher order moments. If the probability distribution is stable, its parameters can be estimated on the basis of readings taken over a long period of time. The air pollution of a city could be reported in the published data in terms of these parameters. These parameters in turn could be used to characterize exposure in empirical research.

3. Multicollinearity

When two pollutants are both thought to be related to an "effect" variable such as mortality rate, and when multiple regression techniques are used to estimate the hypothesized relationship, the process of estimation may be complicated by the problems of multicollinearity. Thus, differences in mortality rates and property value differentials have been associated with differences in the levels of both suspended particulates and sulfates.

For example, suppose the hypothesized relationship is as follows:

$$M = a_o + a_iP + a_2S + a_3Z + \varepsilon \qquad (1)$$

where M = mortality rate
P = sulfate concentration
Z = an index of other variables
e = disturbance term

Suppose further that P and S are positively correlated, producing multicollinearity.

It is important to distinguish between problems in estimating the coefficients for equation (1), and problems in using equation (1) for prediction of mortality rates. It can be shown that when equation (1) is estimated with multicollinearity present, the estimates of a_1 and a_2 will be unbiased. However, they are likely to be imprecise in the sense that the estimates will have relatively large standard errors. In fact, it is possible that the equation may have an R^2 well over 0.95, with none of the regression coefficient estimates being significantly different from zero. It is also possible that estimates may have the wrong sign. But it is important to note that, while the individual coefficient estimates may be imprecise, the equation as a whole may still provide good estimates of mortality rates when the independent variables are known.

Now suppose that equation (1) has been estimated and that the estimate of a_2 was insignificant by the ordinary statistical criterion. One might be tempted to drop the sulfate variable and estimate a new equation (2):

$$M = \acute{a}_o + \acute{a}_iP + \acute{a}_3Z + \acute{e} \qquad (2)$$

However, this would be incorrect. The estimate of $\acute{a}_1$ will be biased. Given a positive correlation between P and the omitted sulfate variable, it can be shown that $\acute{a}_1 > a_1$ This is because the estimate reflects not only the partial relationship between P and M, but also part of the relationship between the omitted variable and M. Similarly, if P were dropped and the equation were estimated with only the S, the estimated coefficient for the S variable would be biased upward.

In summary, when the regression equation is to be used to predict changes in the dependent variables, the correct procedure is to use all variables and all coefficients, including those which are insignificant, to predict changes in the dependent variable. In the case of air pollution health benefits, multicollinearity does not pose insuperable barriers to benefit estimation. However, in the case of the property value approach to air pollution control benefits, the problems are more severe.

This is because benefits are not measured by changes in property values stemming from changes in pollution levels (Freeman, 1974). Rather, the partial relationship between the pollution variable and property values is used to determine a marginal willingness to pay function. Where there is multicollinearity between a pair of independent variables (e.g., two pollution variables, or pollution and distance from central business district), this partial relationship can be estimated only imperfectly or imprecisely. In other words, the standard error of the pollution coefficient will be high. This uncertainty should be reflected in the final benefit figure calculated from the regression equation.

Most of the published property value and mortality studies use only one or, at most, two air pollution variables, for example some measure of particulates and sulfates. But if there are other air pollutants which also affect the property value or mortality (for example, oxidants or nitrogen oxides) and these other pollutants are correlated with the pollution variables included in the estimating equation, then the estimates will be biased upward, as was pointed out above. I am not aware of any studies that have attempted to determine the significance of this problem.

Published studies of Lave and Seskin have focused primarily on long-run or chronic effects of exposures to relative low levels of pollutants. They have found that long-term measures, such as annual average and minimum bi-weekly exposures work best in their regression equations. This raises the question of whether benefit estimates based on the Lave-Seskin equations might be missing the contribution to mortality made by health effects associated with short-term exposure to high levels of pollutants. A consideration of the multicollinearity problem suggests that mortality equations should be estimated with, say, two sulfate variables, one to reflect the presence of short-term high level exposures and other to reflect long-term chronic exposures. These two variables are likely to be correlated and when their coefficients are estimated in the same equation, the standard errors may be high. However, to omit one of the variables on those grounds will lead to biased estimates of the coefficient for the other variable. Since the objective of obtaining estimates of air pollution benefits is best served by obtaining regressions with unbiased estimates and high predictive power, insignificant variables should not be omitted where multicollinearity is present.

F. PREPARING NATIONAL ESTIMATES

The conceptually correct approach to aggregation of benefits at the national level is to examine each region separately, within that region to analyze each pollutant and each effect separately, then to sum benefit measures across all effects, all pollutants, and all regions to get the national figure. This section reviews the criteria for selection of regional studies and the process of aggregation from these building blocks.

1. Criteria

National estimates of benefits can be judged in terms of two general considerations. The first looks at the underlying benefit study used as a building block. The second general criterion is the logic underlying the extension or aggregation from the building block benefit study to the national level. The following criteria are intended to provide a benchmark against which to evaluate specific benefit studies which are to be used as building blocks.

[illegible] he objective of the exercise is determination of values, a technique should lead to monetary measures of values or benefits. This means, for example, that a measurement technique which predicts the increase in recreation user-days associated with a given reduction in pollution does not meet this criterion. For, although the information is useful, it does not fully meet the needs of water resource planners for benefit measures which are commensurable with their monetary estimates of pollution control costs. Similarly, while studies of the relationship between mortality and air pollution are essential building blocks in the estimation of benefits, they do not determine value. In some cases, the analyst may not have credible estimates of individual values. In these circumstances, he may be justified in making some explicit assumption about unit values, e.g., value per death avoided, and determining the implications of alternative value judgments.

The technique and estimating procedures should be based analytically and empirically on individual behavior and preference. Some measures of the value of reduced mortality have been based upon the earnings of affected individuals (Lave and Seskin, 1970). Such measures do not meet this criterion, since there is no known relationship between willingness to pay, on the one hand, and earnings, on the other. The most obvious limitation of the lost earnings measure is that it places no value on the lives or health of those who are not working for reasons of age, sex, or other factors.

The measures of use and value should be related to changes in pollution levels. For example, the analysis of the demand for water-based recreation is not adequate, unless the analysis shows how that demand is affected by changes in pollution and the quality of the water bodies being analyzed. Particularly in the realm of water quality, the difficulty of establishing the relationship between quality and use is a major barrier to better estimates of benefits. We do not yet have a clear idea of what indexes of water quality are relevant to recreational uses of the water, and how people will respond to changes in quality parameters. And furthermore, the links between many of the more subtle water quality parameters and discharge rates are not understood.

Benefit estimates should be based upon a correctly specified theoretical model of individual behavior and the relationships among economic units. The logic of the model must be internally consistent and also be consistent with established theory. When observed relationships are measured empirically, without benefit of an underlying theoretical model, researchers may be led to make faulty or erroneous interpretations of the data. An important example is the discovery by early researchers that land value and air pollution levels were inversely related in urban areas, _ceteris paribus_. They then assumed that changes in welfare associated with reduced pollution would be adequately measured by the associated increases in land values. However, subsequent research based upon theoretical models of urban land markets, has shown that this assumption is not true in general. (Freeman, 1974; Lind, 1973; National Academy of Sciences, 1974, Chapter 4).

The actual measures used in the empirical work should correspond to the variables of the theoretical model. For example, a priori reasoning about the relationship between air pollution exposure and mortality suggests that the time profile of cumulaive exposure of an individual is the appropriate independent or ausal variable. But most empirical research on the air pollution-ortality relationship has been based upon air pollution measurements taken at a point in time or over a short period, and at a specific geographic location within an urban area. Thus, the empirical measure of air pollution is not perfectly correlated with the measure called for by the correctly specified theoretical model. The correct theoretical measure may not be available, but the analyst must be sensitive to the problems that might be caused by the lack of correspondence between the theoretically correct variable and the one actually used.

Benefit studies should use the empirical techniques appropriate to the theoretical model and the data at hand. Empirical techniques should be able to cope with such problems as multicollinearity, simultaneity, and identification problems. Empirical techniques which do not adequately control for other variables should be used with great caution. Researchers should be sensitive to the problems caused by misspecification of the variables used and of the functional forms estimated.

No benefit study yet done is completely satisfactory in terms of all six of these criteria. Yet, the researcher and analyst need to push on and do the best they can with available data and analytical techniques using these criteria as benchmarks. Part of the art of benefit analysis involves a sensitivity to the gap between the ideal and the available and knowing how much confidence to place in the estimates being generated. At some point, the problems become so great and likely margins of error so large that the effort is not producing usable numbers.

2. Aggregation from Building Blocks

A correct approach to estimating national benefits from valid building blocks involves several distinct steps. These are now described in more detail.

The first step is to specify the present levels of pollution in each region or unit of analysis, and to postulate the change in pollution or environmental quality which is to be the subject of analysis. The postulated changes in pollution will be determined by the nature of the policy question to which the national benefit estimate is to be addressed. For example, in the case of air pollution, it might be most useful to postulate the changes in air pollution required to achieve national primary standards throughout the country. In the case of water pollution, one could postulate changes necessary to achieve the water quality standards established under the 1965 law. But an analysis which postulates a 50 percent across the board reduction in air pollution does not shed much light on important policy issues.

The next step is to determine the functional relationship between use of the environmental amenity and environmental quality. Use is likely to be a function not only of quality, but also of socioeconomic and other variables which will differ across regions. For example, differences among regions in industrial composition, or importance of agriculture, may mean that the same changes in environmental quality will have different physical effects in different regions.

The third step is to use the functional relationships described above to predict the changes in use for each region conditional upon its postulated change in environmental quality and its other socioeconomic variables.

The next step is to estimate the functional relationship between uses of the environment and marginal value or willingness to pay. This relationship will also be a function of socioeconomic variables and other factors (such as the availability of substitutes as in the case of recreation).

The fifth step is to calculate the value or monetary benefit measure for each region on the basis of predicted change in use and other factors influencing demand or marginal willingness to pay.

The final step consists of summing the predicted benefits across all regions to obtain the national estimate.

These six steps are offered as a benchmark against which to evaluate the procedures used to generate existing national benefit estimates. I know of no study which has followed faithfully all six steps as outlined here. Most of the studies take a shortcut by generalizing from the results of one or two specific studies to the nation as a whole. Sometimes this is reasonable, where it can be reasonably assumed that the variables involved are constant across regions. In other cases, the generalization may involve significant distortions and inaccuracies. Because of the great variety of cases and types of benefits, it is not possible to state general rules as to when such assumptions are valid.

3. Specific Examples

I will now turn to some specific suggestions for generating national estimates for pollution control benefits in the three quantitatively most significant areas: health benefits from air pollution control, aesthetic benefits from air pollution control (property values), and recreation benefits from water pollution control. I believe that it is possible to develop useful estimates of pollution control benefits in these three areas on the basis of present theory and analytical techniques.

In the areas of health and property value benefits from air pollution control, data bases exist which would permit useful although not definitive benefit estimates. Existing published estimates in these two areas (Waddell, 1974) have used faulty procedures to move from the underlying functional relationships to estimates of benefit and aggregation to the national level. In the case of water-based recreation, the necessary data base does not presently exist. However, work in progress by the National Planning Association under contract to the National Commission on Water Quality may help to close this gap.

A major component of total air pollution control benefits is accounted for by the property value approach to aesthetics. Most of the property value studies have used data from the decennial censuses. The census collects data from each homeowner respondent on the owner's estimate of market value. It would be highly desirable to improve the data base for property value studies by obtaining value estimates more directly related to market transactions, and by obtaining estimates more frequently than during census years. Crocker (1970) has shown that this is possible and more investigators should follow his lead.

Consider the benefits accruing to households due to improvements in air quality at their residence site. The first step is to analyze the property value-air pollution relationship for a given city using the appropriate regression techniques. The first derivative of the property value function with respect to air quality can be interpreted as a locus of household equilibrium marginal willingnesses to pay. It is necessary to make some assumption about the shape of each household's marginal willingness to pay function through that known equilibrium point. Several alternative assumptions were described by Freeman (1974). Next, for each unit of analysis (household, block, census tract), a change in air quality is postulated and, for each unit of analysis, the area under the assumed marginal willingness-to-pay curve between the original air quality level and the postulated new clean air point is determined by integration. Finally, these are summed across all units to determine the estimate of air pollution control benefits for that city. (Freeman, 1974; National Academy of Sciences, 1974, Chapter 4).

To obtain conceptually correct national estimates, it is necessary to repeat the estimation of the property value-air pollution relationship for each city, then repeat the calculations described above. This is because different cities have different levels of average air pollution, different spatial patterns of air pollution, and different vectors of socioeconomic characteristics. (National Academy of Sciences, 1974, Tables 4-7 and 4-8). I have also described a technique based upon the estimation of hedonic price indices for identifying the demand curve for clean air directly. It requires a pooling of air pollution, property value, and socioeconomic data from several cities. (Rosen, 1974; Nelson, 1975). If the demand curve has been properly drawn, it is then possible to integrate areas under these demand curves for all individuals in all urban areas to obtain a conceptually valid estimate of national benefits.

A shortcut approach would be to review the existing air pollution property value relationships and to construct a synthetic (average) relationship which is assumed to apply to all cities. But this would have a higher margin of error than the method described above. Alternatively, one could carry out this procedure for subsets of cities grouped according to some set of characteristics. Then the postulated changes in air quality could be combined with the appropriate assumption about functional form to compute benefits for each unit of analysis within each city. Finally, these could be summed within each city and across all cities to obtain the national benefit figure.

The present state of the art in health effects research can be characterized as follows. Lave and Seskin have produced a substantial body of research showing an association between mortality and air pollution and a number of less comprehensive studies have corroborated this finding. The Lave-Seskin research is based upon cross sectional studies using U.S. SMSA's as the sample unit. At the other end of the spectrum, a substantial number of micro dose-response relationships have been established for specific clinical manifestations. These are primarily related to high acute dosages, at levels not often experienced in urban areas.

The substantial gap between these two bodies of studies must be closed. At the clinical level, more work should be done to establish the specific mechanisms and cause-effect relationships involved with lower-level, longer-term exposures, such as those found associated with mortality by Lave and Seskin. On the other hand, epidemiological work should begin to focus on more disaggregated research based upon smaller units of analysis. But this work must await the establishment of a better data base on both mortality and morbidity associated with exposure to pollutants.

I would recommend the following procedure for estimating health benefits from air pollution control. First, existing mortality-air pollution studies are reviewed. Either the single best relationship is selected, or a synthetic relationship is constructed which reflects the range of experience and confidence in different estimates revealed in existing studies. For each unit of analysis defined for the mortality relationships selected (e.g., SMSA, city), a change in air pollution levels is postulated. Then for each study the change in mortality based upon the change in air pollution and other socioeconomic variables is computed. It should be noted that, if the selected relationship is linear, the predicted change in mortality is independent of other variables. However, if the function is semi-log or log, the vector of other variables must be incorporated in the calculation. Summing the predicting changes in mortality over all SMSA's will give an aggregate measure of deaths avoided for the nation as a whole due to the postulated air pollution control program. To obtain a monetary measure of benefit, it is presently necessary to make some explicit assumption about the value of deaths avoided or postponed. Morbidity effects can be measured and valued in the same manner.

Unfortunately, the most widely quoted estimate of national health benefits associated with air pollution control did not use a correct method for predicting national changes in mortality. After choosing their "best" regression associating total mortality with measures of suspended particulates, sulfate particles, and several socioeconomic variables, Lave and Seskin (1970) calculated elasticity coefficients of the dependent variable with respect to each of the independent variables at the mean values for all variables. Strictly speaking, the elasticity enables one to calculate the percentage change in the dependent variable for a given percentage change in any independent variable.

If the elasticities are constant throughout (i.e., if a log-log regression form had been estimated), then the elasticity coefficients can be used for any magnitude percentage change in an independent variable for any sample point. However, Lave and Seskin estimated a linear form and it is well known that linear functions have different elasticities throughout the range of the function. Therefore, the calculated elasticity coefficient can strictly speaking only be used to estimate changes in mortality for the "average" city for small changes in its population level. A sample calculation suggests that with relatively low elasticities, as in the case cited, the magnitude of the error in using the same elasticity figure throughout for all of the sample points can be substantial. Therefore, the estimated changes in mortality consequent on a reduction in air pollution must be called into question.

Recreation appears to be the largest category of benefits to be realized from water pollution control. There are two major problem areas in the estimation of national recreation benefits. The first is our ignorance of the relationship between water quality and recreation use or participation. Second, it is very difficult to generalize to the nation as a whole from the small number of studies that have been done on the unit value or shadow price to be attached to a unit of recreation (e.g., a recreation day). *A priori* reasoning suggests that the appropriate shadow price depends upon local socioeconomic characteristics, the availability of substitutes, and taste formation mechanisms, such as the "learning by doing" phenomena. Also, many of the recreation sites which have been studied have unique attributes which make it difficult to separate the value of the general recreation experience from the value attached to those site-specific characteristics.

In estimating the national recreation benefits from water pollution control, there are several points to bear in mind. First, the major barrier to developing adequate estimates of water pollution control benefits is our lack of understanding of the relationship between various measures of water quality, on the one hand, and various recreational uses of water bodies, on the other. The most commonly measured water quality parameters are at best only crude proxies for the more complex vectors of characteristics which influence recreational uses. Second, it is very dangerous to extrapolate predictions of changes in recreation participation or recreation demand from narrowly focused studies of limited geographic areas.

Third, the analysis of recreation benefits must recognize the variety of likely individual responses to changes in the availability of recreation sites. Existing recreationists will increase participation levels; non-participants will become participants; and there will be shifts in the geographic pattern of recreation activity, as recreationists shift from one site to another. Furthermore, there will be both changes in the level and pattern of economic/market transactions associated with recreation, e.g., travel expenditures to recreation sites, and changes in utility levels which have no counterpart in market transactions.

It would be useful to outline briefly the theory of recreation benefits as developed for a single recreation site holding all other relevant economic magnitudes constant. There exists a demand for this recreation site relating quantity demanded of recreation services (e.g., in recreation days) to price. This can also be interpreted as a marginal willingness to pay curve, relating marginal value to quantity. This demand curve is plotted holding income, prices and availability of substitutes and alternatives, and the quality of this recreation site constant. When price is known, as indicated by the line P in Figure II-3, actual recreation use for quantity demanded can be predicted. Of course, price could be zero. When the facility is polluted and the demand curve with pollution is as shown, the quantity of recreation days would be 0-Q_1.

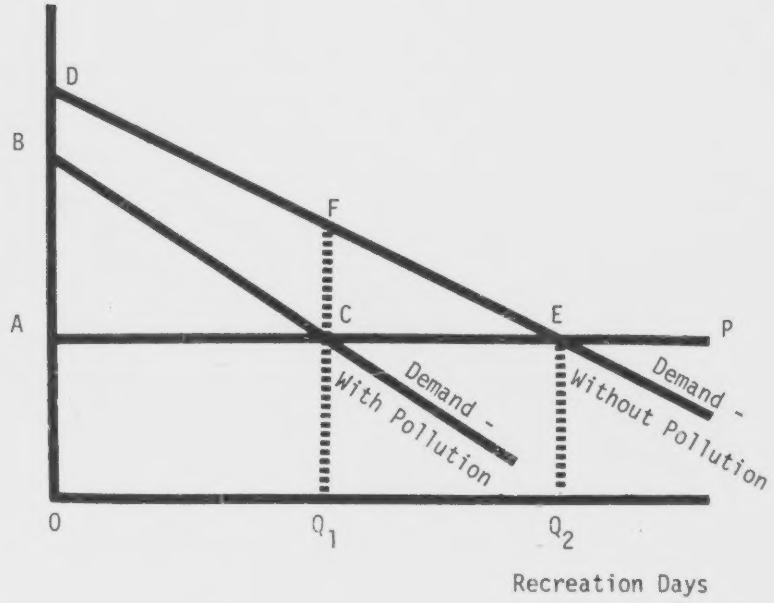


Figure II-3. Recreational Benefits of Water Pollution Control

The net value or rent attributable to this recreation site is the area A-B-C. This is a consumer surplus measure of value. Now, let us assume that a pollution control program increases water quality at this site. In economic terms, the effect is to shift the demand curve out and to the right - the new demand curve as shown in the figure. The net economic benefit of this cleanup is the increase in consumer surplus, i.e., the area between the two demand curves, B-C-E-D.

The net benefit can be divided into two categories. The first is the increase in utility or consumer surplus to those 0-Q_1 users who were using the facility even when polluted. This is the area B-C-F-D. This area represents their increase in willingness to pay to maintain present use rates at this recreation site rather than do without. In addition, the greater attractiveness of this site relative to alternative recreation sites and alternative consumption activities, other than recreation, results in an increase in recreation days at this site equal to Q_1-Q_2. There is a benefit associated with this increase in use which is equal to the area C-E-F.

In utilizing such a measure of benefit, there is no need to take into account changes in recreation use at other sites, savings in travel cost, or whatever. These are all reflected within the B-C-E-D, benefit measure. When there are simultaneous changes in quality or availability at several recreation sites, the theoretical and empirical analysis becomes a bit more complicated. (Burt and Brewer, 1971).

As the analysis of Figure II-3 shows, changes in water quality will be associated with both changes in willingness to pay and changes in quantity of participation. This suggests that the simultaneous pursuit of two research paths might be most appropriate. The two are a national recreation participation survey incorporating socioeconomic variables as well as quality and quantity availability variables, and micro efforts to measures shifts in the demand curve for specific sites as water quality changes.

G. CONCLUSIONS

Four questions were raised at the outset of this paper. The first was: "Would national benefit estimates be useful?" In Section B, several important environmental policy issues were described which would certainly be illuminated by better information on benefits. Even when environmental policy issues are not made in accordance with a strict benefit cost rule, benefit and cost magnitudes are still important considerations in environmental decision making.

The second question was: "Will the state of the art permit the development of national estimates of benefits?" In my judgment, the economic theory and analytical techniques for valuing benefits for most classes of benefits are relatively well developed. There are still major unresolved theoretical and analytical issues with respect to valuing health and life benefits. But in other areas, for example, land value, travel cost approach to recreation, net factor income and productivity approaches, etc., the validity of the theoretical framework is now well established.

However, major problems remain at the interface between the economic dimensions of the benefits problem and those dimensions dealt with by the other sciences. There are major gaps in our ability to relate changes in use of the environment to changes in the environmental quality parameters. Examples include dose-response relationships for air and water pollutants, and relationships between water quality and recreation and fishing benefits.

It is fair to say that we know much more now about the nature and magnitude of air and water pollution control benefits than we did, say, five years ago. A review of Ridker's (1967) valiant effort is instructive in this regard, both in terms of the very crude conceptual framework and analytical technique and the almost non-existent data base he had to work with.

Turning specifically to air pollution, it is now possible to use existing techniques and data to obtain tentative estimates of air pollution health and property value benefits. Obtaining these estimates will involve the explicit use of value judgments and assumptions about certain magnitudes; and there will be some degree of uncertainty in the final figures. But part of the present state of the art includes a consistent framework and language for expressing this uncertainty in probalistic terms. Furthermore, these estimates will be reasonable in the sense that we are more likely to hit the correct figure by using these techniques than we are by drawing numbers out of a hat.

In the case of water pollution, medical knowledge of potential health benefits is simply inadequate. And for the major class of water pollution control benefits, recreation, the data base for relating water quality changes to changes in recreation use is not adequate. I would conclude that the state of the art and data do not permit reasonable water pollution control benefit estimates.

Are there any "hopeless cases?" For purposes of this discussion, we can define "hopeless" as a situation where the marginal cost of additional useful information is infinite. By this definition, there are no hopeless cases in the area of benefit measurement. Consider the problem of valuing human life. One might argue that although individuals do make decisions which imply money values for changes in life expectancy, these decisions reveal a multiplicity of values for different individuals and different circumstances. However, the search for a single unique value of life applicable to all situations is unnecessary. The absence of a unique single price or marginal value is a characteristic of all public goods, such as the demand for clean air and the unit value of recreation experiences. The point is that our understanding of the valuation problem can be improved by further research. It is in this sense that the problem is not hopeless.

There are, however, some insoluble problems in the area of benefit estimation. They are insoluble because they involve value judgments and fundamental questions of equity, not primarily questions of economic theory and measurement. We have uncovered three manifestations of this fundamental problem in the course of our discussion. First, there is no objective criterion for judging or evaluating different distributions of benefits and costs. Thus, although distributions of benefits and costs can be described for decision makers, this information cannot be incorporated into a comprehensive, objective decision rule without the prior specification of some set of equity weights. Second, our estimates of benefits are derived from the price information revealed by existing markets. This price information derives its validity from the implicit acceptance of the existing distribution of wealth which produced the existing set of prices. If the present distribution of wealth is judged to be unacceptable on ethical grounds, no meaningful welfare statements can be derived from the existing price information. And third is the evaluation of potentially massive or catastrophic environmental damages which may occur at some more distant time in the future, i.e., so-called intergenerational effects.

The third question was: "Do recently published estimates of national benefits adequately reflect the state of the art?" In other words, do these estimates make the best use of presently available analytical techniques and data? Although a detailed answer is beyond the scope of this paper, in summary, the answer is "no". However, the cost of generating estimates which do reflect the state of the art would be relatively small; and in my judgment, the benefits of doing so justify incurring the cost.

The final question was: "How can present national benefit estimates be improved?" The recommendations for gathering additional data and more effective utilization of existing data are presented in the next section.

H. RECOMMENDATIONS

Recommendations for improvements in benefit estimation here fall into three categories: those dealing with improvements in the basic data and analytical techniques; those dealing with improved uses of existing data; and one proposing the initiation of ex post measurements of realized benefits.

1. Basic Data and Analytical Techniques

Earlier we distinguished between measuring effects and assigning of values, both necessary steps in the determination of benefit estimates. But in the key areas of mortality and morbidity from air pollution, and in the lesser areas of vegetation and materials damages from air pollution, as well as sports and commercial fisheries and production benefits from water pollution control, the measurement of these effects lies largely outside the realm of economics. And economists' efforts to assign values and estimate benefits in these areas must await better information on physical effects.

The apparent importance of health effects of air pollutants suggests a high payoff for more information on dose-response relationships. More effort should be devoted to large-sample carefully controlled epidemiological studies to examine both long-term chronic and short-term acute effects of air pollutants. An effort should be made to move beyond the inter-urban comparisons of the sort done by Lave and Seskin. Perhaps the population at risk data base developed for EPA can be used to carry out epidemiological studies disaggregated within urban areas. Also, some attention should be given to epidemiological studies of water pollution health effects. In particular, attention should be given to the problems of persistent organic chemicals, and viral pathogens in drinking water.

Research efforts to determine health and other kinds of effects should be designed so as to complement and support efforts to determine values. For example, sample surveys to determine morbidity effects due to air pollution should include questions to obtain socioeconomic data. This is important not only because socioeconomic variables are themselves associated with health status and must be controlled for in estimating health effects, but also because if these data are part of the effects study, they may facilitate the later assignment of economic values.

Research on the value of human life should be extended in two directions. First, the individual choice/willingness to pay model where one element of choice is a small change in the probability of death should be further developed. (Bergstrom, 1975; Zeckhauser, 1975; Thaler and Rosen, 1974). One important extension is to examine the implications of changes in the shape of the probability distribution of expected life. Second, government decisions and other collective decisions involving safety, health, medical research, etc., should be carefully analyzed to determine the implied or explicit values placed on human life or changes in probability of death. This effort may give some insight into collective attitudes toward life valuations, and it may also stimulate efforts to achieve greater consistency among public sector decision makers in this area.

The U.S. EPA should commission a series of micro region-specific efforts to estimate the demand curves for specific recreation sites using the Clawson-Knetsch travel cost approach and to relate shifts in the demand curve to changes in various water quality parameters. This series of studies should be designed and coordinated so as to control cross studies for socioeconomic variables, the availability of substitutes and alternative sites, and other regional differences in recreation behavior. The objective of these studies would be to identify the underlying functional relationship between quality and willingness to pay for recreation experiences. If this effort is successful, it should be possible to generalize the results to additional sites and regions. This series of studies would emphasize the determination of the demand curve and evaluation.

Another study should address changes in the quantity of use on the basis of a large, carefully constructed survey of recreation participation. Earlier surveys have not adequately dealt with the quantity and quality of the available water based recreation sites and the availability and quality of alternative forms of recreation opportunity as determinants of water based recreation participation rates. If such a data base were established, and participation rates could be successfully related to the quantity and quality of recreation opportunity, then the prediction of changes in participation rates associated with specific water pollution control programs would be relatively straightforward. Of course, this approach would not reveal values or shadow prices; nor would it capture the change in utility of existing recreationists.

The model being developed by the National Planning Association under contract to the National Commission on Water Quality appears to be a very promising step in the right direction. However, it does not appear that that model can be adequately developed given existing time and resource constraints. That research effort should be broadened and continued at a generous level of support. Independently, a series of travel cost and similar studies should be initiated in an effort to determine unit values for recreation days, and, more importantly, the way in which they vary with changes in water quality and other attributes of particular recreation sites.

There should be carefully constructed experiments with the interview/questionnaire techniques for estimating willingness-to-pay for reduction in pollution. These experiments should be coordinated with studies based on other analytical techniques in an effort to provide a cross check or validation of benefit estimates obtained by different approaches.

2. Use of Existing Data

The Lave and Seskin air pollution-mortality regression equations should be used to predict changes in mortality by SMSA for changes in air quality necessary to meet national primary air quality standards. These estimates of changes in mortality should be combined with alternative assumptions about the value of human life to calculate a range of benefit estimates.

The Freeman-Rosen technique should be used to compute correct benefit estimates from existing property value studies for individual cities. Also, it may prove useful to commission a series of new property value studies using improved measures of property value and a consistent theoretical model and empirical technique for all cities. These studies should be designed to identify the demand curve or willingness-to-pay curve for clean air.

A group of experts should be convened, perhaps under the auspices of the National Academy of Sciences, for the purpose of developing a comprehensive estimate of national benefits of pollution control. The group should be comprised of professional researchers with backgrounds in environmental economics, the economics of project evaluation, econometrics, epidemiology, environmental health, limnology and marine biology, agricultural sciences, and engineering. The group should be asked to review all of the available literature and on-going research on the effects of all classes of pollutants, and to compile their best estimate of national benefits of pollution control for each of the major polluting substances.

The group should utilize a consistent framework for defining and measuring benefits, and consistent techniques and methodologies for moving from building block studies to national estimates. It should utilize all available data, making use of their expert judgments as to relative quality and accuracy of parameters and relationships from different studies. The group should be asked to make recommendations to guide further research to close gaps in information that are identified by the group. A new group should be convened every three to four years in order to review new data and to prepare new national benefit estimates.

3. Ex Post Evaluation

A careful and comprehensive program of ex post analysis of pollution control benefits should be developed and implemented. The period of the seventies will have been characterized by a major commitment of resources to air and water pollution control. It would be penny-wise and pound-foolish not to plan now to allocate one or two percent of the total funds to be spent on pollution control toward measuring and evaluating what we will have bought with that massive expenditure. In one sense, the nation is embarking on a large-scale socioeconomic experiment in altering environmental conditions. We should take advantage of this experiment with a carefully thought out and comprehensive program of data gathering and analysis.

I. REFERENCES

Bergstrom, Theodore, "Preference and Choice in Matters of Life and Death," in press, 1975.

Burt, Oscar, and Durward Brewer, "Estimation of Net Social Benefits from Outdoor Recreation," Econometrica 39(5):813-827, September 1971.

Crocker, Thomas, Urban Air Pollution Damage Functions, University of California, Riverside, PB 197-668, 1970.

Freeman, A. Myrick, III, "A Survey of the Techniques for Measuring the Benefits of Water Quality Improvement," in Henry Peskin and Eugene Seskin, eds., Cost/Benefit Analysis and Water Pollution Policy, The Urban Institute, Washington, D.C., 1975.

_______________________, "On Estimating Air Pollution Control Benefits from Land Value Studies," Journal of Environmental Econonomics and Management I:74-83, 1974.

Haveman, Robert H., and Burton Weisbrod, "The Concept of Benefits in Benefit/Cost Analysis with Emphasis on Water Pollution Control Activities," in Henry Peskin and Eugene Seskin, eds., Cost/Benefit Analysis and Water Pollution Policy, The Urban Institute, Washington, D.C., 1975.

Kneese, Allen, and Orris Herfindahl, Economic Thoery of Natural Resources, Charles Merrill, Columbus, 1974.

Lave, Lester and Eugene Seskin, "Air Pollution and Human Health," Science 169:723-733, 21 August 1970.

Lind, Robert C., "Spatial Equilibrium: The Theory of Rent and the Measurement of Benefits from Public Programs," Quarterly Journal of Economics 87(2):188-207, May 1973.

Mishan, E. J., "Evaluation of Life and Limb: A Theoretical Approach," Journal of Political Economy 79(4):687-705, July/August 1971.

National Academy of Sciences, Air Quality and Automobile Emission Control, A Report by the Coordinating Committee on Air Quality Studies, Vol. 4, The Costs and Benefits of Automobile Emission Control, Washington, D.C., 1974.

_______________________, Principles for Regulatory Decision Making About Chemicals in the Environment, 1975.

Nelson, Jon, "Residential Choice, Hedonic Prices, and the Demand for Urban Air Quality," Pennsylvania State University (in press), 1975.

Ridker, Ronald G., Economic Costs of Air Pollution, Praegar, New York, 1967.

Rosen, Sherwin, "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition," Journal of Political Economy, 1974.

Schelling, Thomas C., "The Life You Save May be Your Own," in Samuel Chase, ed., Problems in Public Expenditure Analysis, Brookings Institution, Washington, 1968.

Thaler, Richard, and Sherwin Rosen, "The Value of Saving a Life: Evidence from the Labor Market," University of Rochester Discussion Paper, 1974.

Waddell, Thomas E., The Economic Damages of Air Pollution, U.S. Environmental Protection Agency, EPA-600/5-74-012, 1974.

Zeckhauser, Richard, Processes for Valuing Lives, Harvard Public Policy Program Discussion Paper #29D., 1975.

III. BENEFITS OF AIR POLLUTION CONTROL

Thomas D. Crocker
University of Wyoming

A. INTRODUCTION

This section presents the purpose and scope of this paper, the techniques for estimating air pollution control benefits, and finally, the organization of this paper.

1. Purpose and Scope

The purpose of this paper is to review and assess the methods available for modeling and measuring the economic benefits of air pollution control. Models of the economic behavior of beneficiaries of air pollution control could be increasingly used to untangle the various financial, economic, and environmental issues relevant to proposed control efforts. Nevertheless, in some instances, attempts to apply these models may already have gone beyond the general understanding of their analytical foundations and their appropriate roles in decision making. In order to evaluate the extent to which this might be true, it is necessary to have a clear idea of the possible purposes of a model of the behavior of beneficiaries of air pollution control.

Fundamentally, a model can have any one or more of three objectives:

- Enhanced understanding of the phenomena being investigated
- Improved ability to predict the future courses of important variables at various levels of disaggregation
- Improved basis for analyzing the economic consequences of specific alternative control policies.

Generally speaking, all three objectives are served better by any model encompassing a greater range of phenomena or one characterized by variables more closely corresponding to observable phenomena, or one permitting the use of more powerful and readily applied estimation techniques.

Among these three objectives, the first is most likely to be of interest to the professional researcher, while the latter two assume greatest relative importance for the decision maker. Moreover, the first requires more emphasis upon formal analytical comprehension, whereas the latter two emphasize empirical implementability. In those parts of economics relevant to the assessment of the benefits of air pollution control, there has frequently been inadequate attention by analytical investigators to possibilities of improved empirical implementation. On the other hand, decision makers have overly encouraged the production of empirical efforts lacking proper analytical foundations. Recognizing these deficiencies, there now appears to be a judgment that research into the economic benefits of air pollution control can ultimately have little to contribute to the improvement of decisions about air pollution control. This paper will attempt to temper this judgment.

The framework of analysis adopted throughout this paper is the market, the interaction of buyers and sellers. The particular interest is those markets in which air pollution is thought to have a substantive impact on buyer and seller valuations. The manner in which the valuations expressed in these markets can be used to infer the value of air pollution control is discussed at some length. Substantial attention is given to the modeling complications introduced by special features of markets such as health and real property in which air pollution is thought to play a significant role. Among these features are multi-dimensional heterogeneity (in which the combination of characteristics embodied in each unit of a good is more or less unique to that unit), costly information, costs of market participation, and institutional and time constraints.

The neglect of these factors results in the omission of entire classes of air pollution control benefits stemming from the amelioration of intertemporal externalities and uncertainty about future levels of air pollution and its effects. This may mean that substantial biases are built into current estimates of air pollution control benefits, even if these current estimates have been established in an analytically and empirically sound fashion.

2. Estimation of Benefits

Estimating techniques employ one of three alternative measures of benefits:

- Alternative cost
- Opportunity cost
- Willingness-to-pay.

The first of these has been employed most frequently because of its great simplicity. However, its failure to consider adjustments that the sufferer can make in response to the presence of air pollution means that it will nearly always yield estimates of benefits that are biased upward. Moreover, because users generally do not employ an explicit analytical model, the approach yields little, if any, information about behavioral phenomena, the future course of important variables, or the consequences of specific alternative control policies.

In contrast, opportunity cost and willingness-to-pay measures require the construction of explicit analytical models of the phenomena being studied. Consequently, investigators with a background in formal economic analysis who are not under severe time constraints tend to employ these two measures. The research problem then becomes primarily one of comprehending economic, rather than physical or biological relations. The investigator is able to describe the behavior of the price or value of air quality with respect to various physical, biological, and economic parameters. Analytical models of health markets, property markets, etc., employing opportunity cost or willingness-to-pay measures are amenable to empirical treatment with either available data or data that can plausibly be obtained. One must, however, be moderately less sanguine about the availability of data to implement models in which uncertainty or intertemporal externalities have a substantive role.

Whatever the analytical and empirical quality of the benefit estimates thus far obtained, they rarely, if ever, make clear the uncertainty of the estimates themselves. All benefits assessment efforts should generate probability distributions for whatever input variables are relevant and then aggregate these distributions to produce a probability distribution for the output measure, air pollution control benefits. Doing so would reduce the amount of useful information that is thrown away and would reduce the susceptibility of benefits estimates to criticism.

In addition, a number of short-term analytical and empirical approaches could yield rapid improvements in the state-of-knowledge. These include:

- Development and empirical implementation of general equilibrium models of property values
- Adoption and empirical implementation of a household production function framework for health effects studies
- Input productivity studies with special emphasis upon human factors of production
- Adoption of economic, rather than physical or biological, perspectives for the construction of environmental quality indices
- Adoption of new techniques from mathematical statistics to test the functional forms of expressions employed to estimate benefits
- Testing of procedures intended to cause interviewees to reveal their true preferences
- Increased use of algorithms intended to enhance the investigator's ability to discriminate among variables

that might contribute to variations in the values assumed by another variable

- Use of sophisticated econometric models of agricultural markets.

3. Organization

The next section presents the conceptual foundations of benefits assessment for any air pollutant and discusses the issues that must be resolved in applying these foundations to the analysis of individual air pollution control decisions. The third section describes each of the primary methods that might be used to estimate the benefits of air pollution control. An attempt is made throughout to relate these methods to a conceptual framework or a model and the practical questions, including data availability, associated with using each method are raised.

The fourth section compiles the most recent empirical efforts and reviews the content of these efforts in terms of the earlier commentary on conceptual foundations and empirical procedures. The last section reviews briefly the role and prospects of benefits assessment in policy decisions and argues for an increased allocation of research effort to the solution of specific analytical problems.

In order to provide the reader with some appreciation of the motivations underlying the occasionally more abstract discussions in the preceding sections, the attachment contains a discussion of the economic benefits for the participants in a single activity of controlling a single class of pollutants in a particular locale.

B. CONCEPTUAL FOUNDATIONS

This section presents the conceptual foundations for assessing the benefits of controlling any air pollutant and takes up the issues that must be resolved in applying these foundations to the analysis of specific control decisions. The presentation covers the motivations for measuring benefits, measurement techniques, and sources of benefits.

1. Motivations for Measuring Benefits

Air pollution control benefit assessments are intended to aid the public decision maker in formulating policy. If neither more nor less meaning is to be attached to these assessments than their underlying analytical foundations justify, then the decision maker must be sensitive to the limitations as well as the strengths of these foundations.

Cost-benefit analysis is an attempt to ascertain the socially valuable resources and services to be gained and lost in the attainment of any particular state of the world. In each state, market prices alone are presumed to embody all relevant information about relative scarcities and to be a sufficient means of allocating resources to their socially most highly valued uses. Price is assumed to be the sole mode of allocation used in voluntary interactions of buyers and sellers. Markets are pervasive; that is, all gains from exchange are quickly exhausted. Price is thus a sufficient measure of social as well as private value. In effect, the objective of cost-benefit analysis is to ascertain what the price structure of any particular state would be when markets are pervasive.

Sophisticated proofs are available in the economics literature showing that states of the world attained in a system in which markets are pervasive are Pareto-efficient: the net social value of output is maximized because no one individual's welfare can be enhanced without reducing the welfare of another individual (Arrow and Hahn, 1971). The price structure to be ascertained via cost-benefit analysis is therefore a Pareto-efficient price structure. It follows then that, insofar as benefits assessments are used by the decision maker as information inputs in policy decisions, he is making the judgment that the benefit valuations established through strictly voluntary exchange in a setting where markets are pervasive are at least one useful means of weighting the alternatives he has before him.

In the practical world outside economics textbooks, all gains from exchange are not exhausted because markets are, in fact, not pervasive. Institutionally fostered monopolistic advantages, technological externalities, such as air pollution, and consumption and production indivisibilities persevere even though their very existence implies the presence of potential gains from exchange. In a general equilibrium setting in which the activities of all pairs of buyers and sellers are interconnected, the presence of an inefficient price structure in one market implies a similar presence in all other markets. If efficiency is defined only for circumstances in which markets are pervasive, and if the activities of all pairs of buyers and sellers are interconnected, then all real observable price structures must be inefficient.

The activity of benefits assessment, when employed for public policy purposes, is a direct recognition that markets for certain goods and services are either nonexistent or incomplete. These goods and services are therefore valued inaccurately in the sense that their market prices diverge from efficient levels as defined by a world of pervasive markets. Benefits assessment employs various techniques to infer the equivalent prices of these non-marketed goods and services from information embodied in the observed market prices of marketed goods and services that are in the same production or consumption process as the non-marketed entity or which are substitutes or complements to it.

The extent of inefficiency reflected in these observed market prices is typically unknown. Unless an empirically implementable general equilibrium model of the economy is available, the extent of inefficiency (remembering that efficiency is typically defined only for a world of pervasive markets) is inherently unknowable. However, one does not do serious violence to accurate benefits assessment if one imposes separability conditions that permit dimissal from consideration of all markets whose goods and services are plausibly only remotely connected to the good or service for which benefits assessments are being performed.

Of course, a contribution to the description of the efficiency benefits of air pollution control need not be the sole or even one of the reasons why a decision maker wants benefits assessments performed. After all, any benefits assessment is simply a description of the price structure effects of a particular change in the state of the world. It is therefore readily used also to describe the effects of a change in air pollution control upon the distribution of income, government tax revenues, or any of a number of other pecuniary and economic questions of interest. Nevertheless, since all of these effects are influenced by the price structure of the market for the services of the atmospheric resource, as well as the price structures of closely related markets, analytically sound descriptions of these effects also require the construction and empirical implementation of a general equilibrium model.

2. Measures of Benefits

Having recognized the type of world to which economic efficiency is generally meant to refer and the implications of this reference for the construction and empirical implementation of models intended to measure air pollution control benefits, it remains to make explicit exactly what is meant by the term "benefits". First, it is necessary to be absolutely clear that the parties to whom the benefits of air pollution control are presumed to accrue are individual persons. Social benefits are simply some aggregate of individual benefits: there does not exist in cost-benefit analysis a concept of the society having an existence independent of the individuals who compose it.

Second, there exists a consistent, discoverable relationship between a change in ambient air pollution levels and the change in the individual's utility or welfare. The latter is interpreted as the benefits accuring to the individual. Central to the logic of this relation is the idea of consumer's surplus. This states that the individual continues to purchase additional units of the ith good until the marginal utility of the additional unit is just equal to the marginal utility of the money he must pay to obtain the additional unit. That is, the individual will be indifferent between keeping his money and consuming an additional unit of the good when the marginal utility of the additional unit is equal to its market price. The difference between what the individual is willing to pay, as determined by the marginal utility he attaches to the unit, and what he has to pay, as determined by market price, is the consumer's surplus for the unit. The sum of the surpluses for all these units is total consumer's surplus.

This concept is illustrated in Figure IV-1, where DD is the demand function, the locus of points depicting the consumer's

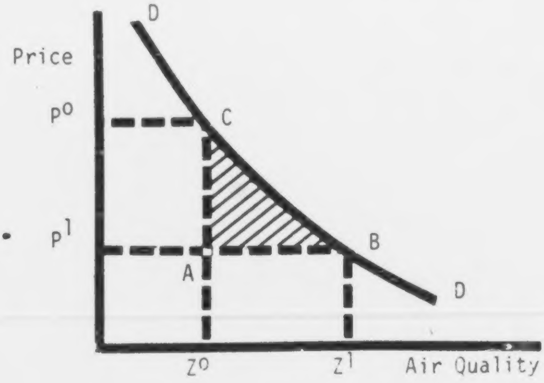


Figure IV-1. Representation of Consumer's Surplus

marginal willingness to pay. The cross-hatched area, ABC, represents the consumer's surplus associated with an improvement in air quality, Z, from Z^0 to Z^1.

In a very important paper, Willig (1974) has shown recently that, in most applications, the difference between the observable consumer's surplus area, ABC of Figure IV-1, and the theoretically correct consumer's surplus of the income-compensated demand function is accurately described as trivial. Willig's (1974) results vindicate analytically the conceptual foundations and great practical value of the consumer's surplus methodology so frequently employed in studies of the benefits of air pollution control. It should nevertheless be noted that there exist several different measures of consumer's surplus, most of which are distinguished by the path the consumer is presumed to follow from one equilibrium position to another. For presentation of a set of criteria with which to evaluate these various measures, see Mohring (1971).

The empirical establishment of the observable surplus becomes considerably more complicated if alternative formulations of the consumer's problem are employed. For example, rather than directly entering the utility function, air pollution might reasonably be viewed as influencing the cost to the consumer of using goods capable of providing utility. Thus, if the absence of respiratory problems is a good from which a consumer derives utility, he will have to expend a greater quantity of valuable resources attaining this absnece in New York City than in Laramie, Wyoming.

An alternative formulation would have the consumer obtain utility directly from the absence of air pollution while also permitting air pollution to affect the costs of other activities or goods from which he obtains utility. Estimation of consumer's surplus using this formulation is more complex than using the traditional formulation, because the goods or activities the use of which air pollution is presumed to affect (e.g., medical services) are treated as inputs into commodities (e.g., the absence of respiratory problems) that are the ultimate objects of the consumer's preferences. In general, even though these formulations will usually increase estimation problems, failure to adopt them in circumstances where reality warrants their adoption would introduce specification errors and thus possibly result in serious errors in the benefit estimates obtained.

As these progressively more complex formulations of the consumer's surplus problem make intuitively clear the greater the generality and realism of the formulation, the greater the difficulty likely to be involved in empirically implementing the propositions falling from the formulation. Nevertheless, because both informational and modeling constraints prohibit the consideration of the full range of commodities, activities, and conditions influencing consumer behavior, some subset of these things must be taken as given. An explicit statement of the formulation on which the empirical effort is based is thus highly desirable. Only then is the reader able to ascertain whether the estimation techniques and the data base employed fit the problem. Equally important, the reader is unable to assign a unique meaning to the empirical results, unless he is made fully aware of the conceptual framework from which these results come.

3. Sources of Pollution Control Benefits

Most discussions of air pollution control benefits explain the existence of economically excessive ambient pollution concentrations in terms of static nonpecuniary externalities. That is, one economic agent's production or utility relations are said to include levels of air pollution chosen by other economic agents, without regard to the effects on the first agent's welfare. The damaged agent in these discussions is implicitly presumed to know with certainty either the magnitude of the effects caused by the air pollution and/or the level of air pollution. Moreover, the reader is customarily permitted to assume that the activities of the pollution perpetrator and the responses of the sufferer to this pollution are contemporaneous.

The restriction of the discussion of the analytical reasons for the existence of air pollution control benefits to static non-pecuniary externalities might explain why two plausibly important causes of air pollution control benefits, intertemporal externalities and uncertainty, have been rarely considered. Their neglect may mean that substantial myopic biases are built into current estimates of benefits.

There appear to be a number of air pollution effects characterized by either or both of the above causes. For example, rain containing acid sulfates may ultimately alter the forest ecosystems of entire regions. Certain long-lived synthetic chemicals, once widely dispersed throughout the economy, and thereby the natural environment, may pose carcinogenic and mutagenic hazards for future generations. An economic agent's activities at one point in time impose constraints upon other economic agents in the future. Insofar as there exists imperfect knowledge of future events, these externalities are a problem worthy of empirical attention.

The air pollution effects associated with intertemporal externalities and uncertainty are characterized by some or all of the following attributes:

- Information asymmetry
- Effects uncertainty
- Public-good type risks
- Low-probability catastrophic losses
- Irreversible effects.

Substantial discrepancies exist in available information about the benefits of increasing an activity, as opposed to the benefits of reducing it. The benefits of automotive travel are relatively easy to calculate; the benefits of reducing automobile travel and its associated air pollution, noise, and aesthetically loathsome landscapes are generally more difficult and expensive to ascertain. For many air pollution phenomena, there is a nearly complete absence of knowledge about the response of physical and biological systems. For example, the overall effect on the earth's climate of increased particulate loadings of the troposphere is highly uncertain. Similarly, the influence on human health of increasing ambient loadings of acid sulfates has not been adequately defined.

The actual or potential risks caused by certain activities are indivisible as between and among economic agents. Moreover, they are frequently borne by very large groups of these agents, including future generations. These groups are unable to reject the risks because they are bound up in a common property resource, e.g., the atmosphere. As used here, risk may refer not only to a lack of complete certainty about one's future wealth, but also to not knowing if one will be alive to enjoy this wealth.

With current information, there exists a probabilistically small possibility of catastrophic or large-scale losses. For example, one potential result of burning large quantities of high sulfur fuels in England is the possibility of greatly and detrimentally altering the forest ecosystems of the Scandinavian countries through formation of acid rain. There is also a possibility that the effects of a particular activity are physically impossible to reverse or cannot be reversed at reasonable cost. Mutagenic changes probably have this characteristic.

The importance of issues embodying substantial uncertainty or ignorance, and therefore the extent to which they are worthy of substantial research effort to assess their benefits and costs, depends in large part upon the decision strategy adopted. If a once-and-for-all commitment is to be made to undertake or fail to undertake an activity, then the likely effects deserve to be specified and measured rather closely. But if a sequential decision procedure is to be followed, the accumulation of knowledge can be delayed. One can then live with a fairly high degree of uncertainty in the present. The cost of an error in choice is not likely to be as great, because it will be relatively less costly to reverse course.

Setting intertemporal externalities and lack of basic knowledge about air pollution effects aside, there is an additional way in which uncertainty might plausibly enter calculations of air pollution control benefits. In the more mundane localized materials damage, property value, interview, and health effects studies of common urban air pollutants that form the bulk of air pollution control benefits studies, the uncertainty of potentially affected individuals about future air pollution levels and the possible influence of this uncertainty upon air pollution control benefits is usually not even mentioned (Crocker, 1971; National Academy of Sciences, 1974).

The disutility the affected individual attaches to future air pollution dosages has been treated as identical in situations where perfect foresight is lacking and in situations where it is present. An affected agent's behavior at a point in time has therefore been viewed as invariant with respect to the probability of error in his forecast of expected air pollution dosages and/or effects. Yet an extremely voluminous analytical and empirical literature is available in economics indicating that in most everyday circumstances, individuals are risk-averse, i.e., uncertainty is costly.

When one admits that one component of air pollution damages may be due to uncertainty of the affected individual about current and future air pollution levels and effects, it is apparent that individual damages from air pollution dosages are by no means independent of the process by which expectations about future dosages and effects are formed. That is, realized damages are but present representations of positions taken in the past in response to expected air pollution dosages and effects. Most empirical air pollution control benefit studies have assumed that sufferer adjustments to changes in air pollution dosages and effects are instantaneous. A more appealing hypothesis is that expectations about future air pollution dosages and effects adapt to changes in present dosages and effects only after some lag in time. Thus, if a change has any permanent effect at all, the effect is not registered all at once but is instead distributed over several time periods.

C. EMPIRICAL PROCEDURES

This section reviews some general formulation employed in estimating the benefits of air pollution control. The topics include methods of estimating benefits, availability of data, expression of uncertainty in results, and aggregation procedures.

1. Methods of Estimating Benefits

The general formulations customarily employed in the estimation of air pollution control benefits are:

- Alternative cost
- Opportunity cost
- Willingness to pay.

The alternative cost formulation is employed most frequently because of its simplicity and avoidance of complex economic analysis. The procedure begins with determination of the physical effects of an activity. For example, an agronomist might construct a dose-response function relating ambient concentrations of acid sulfates to the yield of a particular agricultural crop. These effects are then valued in monetary terms. The assigned money value is that minimum cost which would have to be borne in order to return the affected entity to its original state. This implies that all substitution possibilities and other adjustment processes available to the owner of the affected entity are dismissed from consideration. Losses therefore tend to be biased upward in the case of reductions in air quality, and benefits tend to be biased downward in the case of improvements in air quality. If, and only if, no ready adjustments are possible for the owner of the affected entity is the alternative cost formulation a reasonable approximation of the actual losses or benefits.

Wherever these substitution possibilities and adjustment processes are accounted for, the researcher has adopted an "opportunity cost" formulation. In the case of a decline in air quality, a net loss measure is thus obtained. For example, the researcher studying the influence of smog on the behavior of outdoor recreationists would explicitly take into account the stock and the unit price of substitute recreational opportunities. By taking these opportunities into account, the researcher is, in effect, deriving the minimum amount the recreationists would accept to be willing to be subjected to a change in air quality. The presumption is that title to the air resource is held by the parties who would be affected by the change rather than by the potential perpetrator of the change.

Finally, the "willingness-to-pay" formulation underlies the discussion of the entire previous subsection. As noted earlier, this formulation involves the determination of what individuals would be willing to pay in order not to be subjected to a change in air quality. Therefore, the researcher is assuming that title is held by the perpetrators, rather than by those who will be affected.

The ordering of the magnitudes of these formulations can differ from one set of circumstances to another. Frequently, estimates of losses associated with reductions in air quality using the opportunity cost formulation exceed the estimates resulting from the willingness-to-pay formulation. This is due to the difference in fundamental entitlements and therefore the wealth positions of the parties. Estimates obtained using the alternative cost formulation as opposed to the opportunity cost formulation follow no consistent pattern with respect to relative magnitudes. For example, one could reasonably argue that the money necessary to compensate outdoor recreationists for increases in the amount of smog-damaged forest might be relatively small when compared with the alternative of returning the forest to its original state.

The alternative cost method is nearly always used in the "technical coefficients" approach (Anderson and Crocker, 1971). Also, the widely quoted Lave and Seskin (1971) study on the economic aspects of the health effects of air pollution is best described as an alternative cost study. Examples of studies that do not involve air pollution, but show the empirical practicality of willingness-to-pay studies applied to health effects are provided by Acton (1975), Davis and Russell (1972), Feldstein (1971), Grossman (1972), Phelps and Newhouse (1974), and Rossett and Huang (1973).

2. Availability of Data

The extent to which each of the three alternative measures have been employed in investigations of air pollution control benefits has been determined by three factors: the availability of data, the availability of time, and the background of the investigator in formal economic analysis. Use of the alternative cost measure typically requires little background in economic analysis, while allowing the use of accumulated skills in the natural sciences. The necessary economic "analysis" involves little more than the weighting of physical and biological relationships by readily observed market prices.

The investigator has the opportunity to draw upon the more sophisticated developments in economic analysis when he chooses to employ the opportunity cost or the willingness-to-pay measures. Rather than simply using observed market prices as determined by unknown and presumed irrelevant forces, the opportunity cost and the willingness-to-pay measures compel the construction of models of the implicit market for air quality, thus permitting the investigator to describe the behavior of the price or value of air quality with respect to various physical, biological, and economic parameters.

The extent to which observations must be available on the actual values assumed by the elements of each of these three sets of parameters will, of course, vary according to the problem being investigated. It is true, nonetheless, that the available secondary data and readily acquired primary data for the economic parameters of a great many problems have by no means been fully exploited. For example, great masses of data are available in publications of the U.S. Department of Agriculture and other sources allowing the empirical implementation of opportunity cost models of air pollution damage in agricultural markets. Similarly, large secondary data collections from Federal, state and local sources make possible the estimation of hypotheses derived from willingness-to-pay models of property markets.

Even opportunity cost and willingness-to-pay models of the effect of air pollution upon health are amenable to empirical treatment with either available data or data that can be readily obtained. The widely known CHESS studies of U.S. EPA would have provided enormously more valuable information on the health impacts of air pollution if they had initially been designed by economists as well as by biomedical people.

In summary, analytically sophisticated and empirically implementable models for which data are available or can be readily generated do exist. This is not to say that all the economic benefits of air pollution control are readily susceptible to empirical estimation. The point is that a great deal more can be done. The decision maker must judge whether the results are likely to be more useful than estimates obtained via the simplistic alternative cost formulation, or even the intuitive or experiential approaches that are used frequently in political decisions.

The above comments about the availability of data allowing the empirical implementation of opportunity cost and willingness-to-pay measures apply mainly to static externalities. One must be less sanguine with respect to data availability for empirical implementation of economic analysis of intertemporal externalities and risk aversion. The latter is that facet of human preferences responsible for the existence of benefits from the reduction of uncertainty about air pollution effects and levels.

Two approaches have dominated economists' and psychologists' attempts to measure risk aversion. In the first, lotteries are established in a controlled laboratory setting and the investigator, usually a psychologist, attempts to extrapolate the results to real-world situations. Certainly, one can generate a great deal of data in this manner. However, the degree of correspondence between the controlled laboratory and real-world situations is not always apparent. (Lichtenstein, 1965; Pruitt, 1962).

The second approach has been fairly widely used by economists. Here, the observed behavior of individuals in their everyday pursuits is used to infer the value they attach to the reduction of risk to fortune, health, and life. (Fama and MacBeth, 1973; Oi, 1975; Brown and Enke, 1972). The approach is appealing to the professional economist, because it permits the construction of models of the behavior of economic agents, the formal derivation of testable propositions, and the application of opportunity cost or willingness-to-pay measures of benefits. However, its usefulness is limited by data availability, at least with respect to health and life.

A number of difficulties may be attributed to the public good type risks that characterize air pollution. These are borne by large groups of economic agents, including future generations. That is, the population exposed to deleterious ambient levels of air pollution typically involves a wide cross-section of ages, incomes, medical histories, employments, and other factors.

The most available data, permitting ready inferences about economic agents' voluntary willingnesses-to-pay to avoid risk to health and life are found in the area of industrial safety. However, since netiher the medical backgrounds nor other personal attributes of industrial workers are representative of the population of a typical urban area, the extrapolation of these workers' health and life risk valuations to entire human populations can be done only with some trepidation. On the one hand, industrial workers may, as a group, simply have less or more innate aversion to risk than do other identifiable groups within the entire population. In addition, some groups, such as university professors and government or private bureaucrats, may have less accumulated experience with situations posing risks to health and life. Given more experience, their attitudes may be altered.

There exists at least one source of readily available data on the risk aversion of representative individual economic agents that has not been fully exploited. This involves the voluntary consumption or use of goods which carries obvious and generally acknowledged risk to health and/or life. For example, certain automobiles are widely known to be safer than other automobiles. In effect, the safety features of the automobile are weighed by the purchaser against its other features and its price relative to other automobiles and perhaps other modes of transportation. The question, nevertheless, remains as to how one extrapolates the agent's valuation of risk to health and life in the context of an automobile to his valuation of risk to health and life in the context of air pollution.

Intertemporal externalities are, of course, intimately tied to the presence of uncertainty and risk aversion. These externalities are complicated, however, by the integral part played in their determination by irreversible effects and the passage of time. Analytical efforts in this area have thus far concentrated upon the nature of the adjustments that must be made in traditional benefit-cost evaluations of alterations of natural environments in order to account for irreversibilities, uncertain future effects, etc. However, these efforts typically fail to supply exact quantitative adjustments for these evaluations, nor do they provide computational algorithms indicating the form, type, and quantity of data required for empirical implementation. Without such knowledge, one cannot state whether the requisite data is, in fact, already available or easily obtainable.

Nevertheless, it should be noted that, in particular cases not involving air pollution, some investigators have managed to implement empirically at least a part of the relevant analysis. (Krutilla and Fisher, 1975). These partially successful empirical efforts have occurred in geographical areas where detailed data have been available on likely future technological developments, environmental carrying capacities, and demand patterns for uses based on the existence of a natural environment, as well as for uses involving the transformation of a natural environment.

3. Expression of Uncertainty in Results

Even if the world is a purely deterministic place, it is indeed unlikely that it would ever be worthwhile to accumulate enough data about air pollution problems to eliminate all possible sources of error in benefit estimates. Errors in measurement and simple absences of observations on key variables would persist. In spite of this rather obvious point, estimates of air pollution control benefits are, for the most part, compiled and reported in terms of a single outcome that fails to take account of valuable information about the extent of uncertainty in the reported estimates. The commonly accepted procedure in benefits assessment calls for the calculation of the benefits from each alternative action and for the use of political and economic criteria to choose among these on the basis of expected returns. But except by chance, single-valued benefit estimates must always be in error.

The uncertainty problem discussed in this subsection occurs because many of the variables affecting an air pollution control plan are neither subject to the control of the decision maker nor fully captured in the empirical implementation of any model constructed by the benefit assessor. These variables include property rights structures, technological change, prices, micro-climates, etc. Hence, in contrast to commonly accepted procedures, benefits assessment that takes full account of uncertainty requires: judgments about the likely pattern of behavior of these noncontrollable variables; calculation of an entire set of outcomes or returns for each ambient air concentration; and criteria for choosing among concentrations on the basis of sets of possible benefits for each level of control.

On those occasions when uncertainty has been explicitly taken into account, range sensitivity tests have typically been used to account for lack of knowledge about the behavior of different relationships or the values assumed by particular parameters. Waddell (1974), for example, includes upper and lower bounds and "best guesses" for various air pollution damage categories. An alternative procedure is to generate probability distributions for whatever input variables are relevant and then aggregate these distributions to produce a probability distribution for the output measure, i.e., air pollution control benefits. In an interesting application of this latter approach, Mercer and Morgan (1975) have successfully applied the Weibull (1939) family of distributions, showing that the amount of valuable information made available to the decision maker is enhanced significantly (see also Pouliquen, 1970).

The probabilistic approach to presentation of benefit estimates has many advantages, not the least of which is that it permits the investigator to incorporate accumulated wisdom and intuition into the analysis in an explicit and communicable fashion. If research resources are scarce, individuals who have had long experience in working in an area frequently have a "feel" for the structure of the problem, which permits them to assign subjective probabilities to various outcomes. Some people argue that such evidence should be dismissed on the grounds that it is not "objective", but this argument is badly mistaken. It is difficult to understand why the objective specification of uncertainty should be so important, when the criteria used for choosing among alternative models and oftentimes the model choices themselves are subjective.

Another major advantage of the suggested probability approach is that it does not throw away useful information. For example, in attempting to assess air pollution damages to commercial crops, the biochemist might specify the "best" of several dose-response functions relating crop yield to ambient concentrations of a particular pollutant. In the absence of a thoroughly coordinated research effort in which the economist specifies the variables, units of measure, and sampling procedures, it is possible that the biochemist's conception of best does not accord with that of the economist. It is then up to the economist, who usually is utterly illiterate in biochemistry, to translate the biochemist's results into something useful for purposes of economic analysis. By requiring that a probability be assigned to the various plausible outcomes, the impact of this decision problem can be greatly improved. (Crocker, 1975).

4. Aggregation Procedures

Any estimate of national air pollution control benefits is an index number. That is, a variety of relationships of multiple dimensionality are collapsed into a unique scaler measure. The process of the collapse or aggregation involves an exchange of detailed information about the form and structure of a set of problems in return for tractability and ease of comprehension. The best single source of information on the aggregation problem in economics continues to be Green (1964). The portion of Marschak and Radner (1972) dealing with the one-person team is highly instructive from a decision theory perspective. Fisher and Shell (1972) provide an excellent treatment of the place in index number problems of taste and quality changes, both of which are highly relevant to environmental quality problems.

For a limited number of purposes, it may be of interest to obtain estimates of the total nationwide benefits accruing from air pollution control. An aggregate benefit estimate may provide policy makers with an easily grasped idea of the magnitude of the problem and may therefore give some indication that additional or reduced research resources should be devoted to ascertaining the economic effects across space and time of alternative control strategies. As a possible component of the national accounts, these estimates may also be useful for macroeconomic decision making purposes since they provide some evidence on how the presence of air pollution and attempts to control it alter the nation's aggregate net productivity. An effort, currently underway at the National Bureau of Economic Research to find ways to include environmental quality costs and benefits in the national accounts, is partially described by Peskin (1974).

However, attempts to apply aggregated economic response functions or aggregated magnitudes to local or regional air pollution decision problems introduce sources of error that can lead to substantial discrepancies between expected and realized economic results. These sources of error may remain even if the aggregated functions or magnitudes are used as no more than the points from which disaggregation to the local level is initiated. The initial process of aggregation over locales, and subsequent disaggregation back to locales, may destroy knowledge of the various transformation and substitution possibilities and relative consumer valuations of alternatives in each locale. That is, the weights used to determine the contribution of each type of sufferer and each locale to the aggregate measure may not correspond to the relative weights sufferers in each locale attach. The application of the same set of weights across different sufferers and locales assumes that all sufferers and locales are identical and that existing differences among sufferers and locales will remain unchanged as air pollution levels change. These are indeed strong assumptions.

Existing estimates of the national benefits of air pollution control combine a large number of heterogeneous disaggregated studies dealing with vegetation and materials damages, property values, health effects, and opinion surveys. A majority of these studies employ alternative cost measures, although willingness-to-pay measures have been widely used in the property value studies. The process of aggregation typically employed to obtain these estimates is exemplified by the procedures Waddell (1974) employed to obtain an estimate of aggregate national (residential) property value damages.

Waddell first reviewed a collection of studies that had estimated marginal purchase price functions with respect to sulfur oxides and/or suspended particulates for eight different cities. Interpreting the values of the air quality parameters in these several studies as measures for the average household in each study of *equilibrium* marginal willingness-to-pay at given air quality states and with given demand functions for air quality, he selected a value within the range of these estimated values. By selecting this value within the range of values, he assumed that what was interpreted as the equilibrium marginal willingness-to-pay was the same for all households in all cities. Then, using the further assumption that this assumed equilibrium marginal willingness-to-pay was in fact the actual marginal willingness-to-pay for all air quality states, he multiplied the constant marginal willingness to pay by the number of households and the number of air quality states to obtain an estimate of aggregate national air pollution damages.

In effect, Waddell assumed that the decision problem of each and every household in each urban area of the country could be represented by Figure IV-2, where b is the marginal willingness-to-pay, Q is an air quality level, D is the aggregate national air pollution damage, $\partial P/\partial Q$ is the marginal purchase price function, and $\partial D/\partial Q$ is the function representing marginal willingness to pay for improvements in air quality. Since $\partial D/\partial Q = b$ is invariant with respect to changes in air quality, calculation of that willingness to pay involves only the multiplication of b by whatever change in air quality is postulated. Thus the value to the depicted household of an improvement in air quality ($Q^{**} - Q^*$) is simply $b(Q^{**} - Q^*)$, and the sole distinction one needs to make among households in order to calculate aggregate national damages is to account for the location of each household on the Q axis

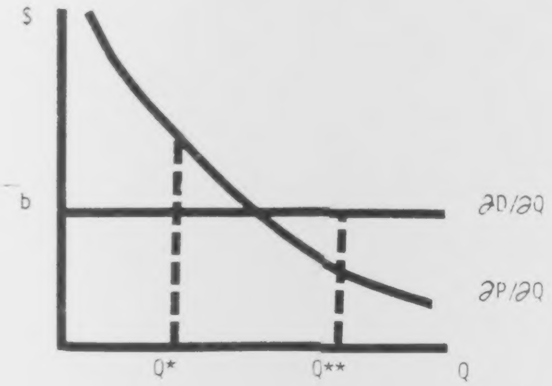


Figure IV-2. Willingness to Pay for Improvement in Air Quality

The above discussion has been devoted to a single aggregation over individual households. Typically, however, estimates of national air pollution control benefits involve aggregation over multiple classes of pollutants, over time, as well as over households. scaler estimates of the national benefits of air pollution control may thus involve two or three distinct types of aggregation, each of which embodies unique assumptions about the similarities among the units undergoing aggregation. Thus,one must choose which type of aggregation is to be performed first in arriving at a scaler representing air pollution control benefits for households, for pollutants, and for time intervals. Moreover, in deciding how to perform the first aggregation, one must take into account how the aggregation for the second and third steps will be carried out.

Finally, it should be noted in passing that the entire discussion in this subsection has presumed that estimates of the aggregate benefits of air pollution control must be constructed from disaggregated, microeconomic studies. The presumption is that empirically measurable microeconomic variables and relations have been derived from microeconomic theory. Given these derivations, aggregated or macro-variables representing national benefits of air pollution control and national ambient air pollution levels have then been defined. Thus far, there has been no intensive analytical effort devoted to constructing an aggregate or macro-theory that will serve to make the macro-variables consistent with the micro-theory and micro-variables. At least in principle, the development of such a theory is by no means a hopeless task. The development of macro-economic theory and national income accounting is evidence of this.

D. SHORT-TERM IMPROVEMENTS IN BENEFITS ASSESSMENT

Most of the discussion to this point has been directed at improvements in the long-term strategy of benefits assessment research. This section seeks to make the reader aware of some theoretical constructs and empirical procedures holding tangible near-term promise. The topics are arranged in order, from the more analytical to the more empirical.

1. General Equilibrium Models of Property Values

Rosen (1974) and Freeman (1974) have recently developed a conceptually improved method of obtaining aggregate national damage estimates that neither assume that the same set of weights applies to each locale and each individual, nor disregards the manner in which burdens are distributed across space, time and individuals. This method employs property value and attributes data for individual urban areas to ascertain a distinct marginal purchase price function for each urban area, using similar data and statistical techniques for each area. Having estimated the marginal purchase price function for each urban area, the data from each area are merged into a single data set. From this data set the relationship of air quality to marginal purchase prices and various household attributes such as income and age is estimated. The value of the parameter attached to the marginal purchase price variable can then be interpreted as the marginal willingness-to-pay for an improvement in air quality.

If the expression relating air quality to marginal purchase prices and various household attributes is nonlinear in the original variables, one can readily obtain scalar measures of marginal willingness-to-pay that can differ from one urban area to another. If this expression is linear in the original variables, one obtains a scalar measure of marginal willingness-to-pay that is constant from one area to another. Nevertheless, this two-stage procedure does permit the distinctive attributes of different urban areas and different households to enter into the determination of average marginal willingness-to-pay.

Summation over the marginal willingness-to-pay estimates for each city in the sample and extrapolation to the nation of the average sample marginal willingness-to-pay, if the sample is thought to be representative of all the urban property markets in the country, provides an estimate of aggregate national air pollution control benefits. This estimation procedure has been recently applied to a single urban area in an extremely interesting and innovative paper by Nelson (1975).

The procedure is soundly grounded in economic theory and is capable of capturing many elusive features of the market, such as multi-dimensional heterogeneity and assorted institutional constraints. In contrast to many other approaches that could be employed, this one can be implemented by widely and thoroughly understood statistical techniques. Finally, a multitude of data, most of which is isomorphic with the theoretical parameters, is readily available.

The Rosen-Freeman estimation procedure forgoes far less information than studies in the other benefit categories when aggregated to the national level. It thus becomes worthwhile to invest substantial analytical and empirical research effort in establishing the extent to which health effects, materials damages, etc., are registered in property values. Insight can then be gained into the decision value of the estimates likely to be obtained by investing further research resources in the development of the other benefit categories. A serious effort should be made to implement empirically the Rosen (1974) and Freeman (1974) estimation procedure in a single coordinated research project, in order to obtain national estimates of the benefits of air pollution control.

2. Household Production Function

There is a common perception that the reduction of health effects constitutes, both absolutely and at the margin, the greatest benefit of air pollution control. Substantive opportunity to test this perception is now available in the form of an analytical framework commonly known as the household production function.

Fundamentally, this approach views the consumer as combining market-purchased goods and his own resources to produce a state of health; that is, medical services and other remedial and precautionary measures are not desired for their own sake but are instead used because they reduce the probability that certain states of the world will occur or because they reduce the loss to the consumer, given the occurrence of certain states of the world. The properties of these household production functions for states of health can readily be perceived as being determined by the state of the household's consumption technology in precisely the same manner that the properties of conventional production functions of firms are determined by the state of standard production technology. Conceptually, air pollution is thus considered as an exogenous factor that detrimentally influences the state of health likely to be attained with a given mix and magnitude of household inputs.

The household production function approach to the theory of the consumer is consistent with alternative cost, opportunity cost, or willingness-to-pay measures of benefits of air pollution control. The alternative cost measure, for example, requires investigation of the ways in which the consumer can, under given ambient air pollution conditions, combine market-purchased goods and services as well as his own resources to produce a particular state of health. Development of opportunity cost or willingness-to-pay measures would, of course, require that the consumer's choice process among alternative states of health be accounted for. The theoretical development of these latter two measures within the household production function framework is set forth in Rosen (1974). Evidence is abundant that empirically sound opportunity cost and willingness-to-pay measures can be obtained via the approach for such nonmarket activities as church attendance, human fertility, education, outdoor recreation, medical services, and a variety of other topics.

Previous studies of the economic benefits of reducing the health effects of air pollution neglect, among other things, the value of the leisure time the individual loses while he is ill, and fail to account for individuals who are nonparticipants in the work force or who refuse medical services. Moreover, these studies do not recognize that the consumer may be uncertain about the covariation of air pollution and health effects and about the "productivity" of particular precautionary or remedial activities. Finally, previous studies have abstracted from the possibility of the individual learning about effects and about the productivity of various activities as well as the possibility that he eventually becomes acclimatized to air pollution and thus attaches less relative importance to its presence.

The major advantage of the household production approach is that it provides an analytical framework for the resolution of the issues cited above. U.S. EPA should encourage research efforts that attempt to establish in detail the empirical observations required to gain the necessary insights from the analytical perspective of household production functions.

3. Input Productivity Studies

Past studies of the economic effects of air pollution on production inputs have focused entirely on specific inputs without giving attention to the manner in which these inputs are involved in a production process. This is due to the universal absence in these studies of an explicit model of producer behavior. Moreover, these studies have dealt with non-human inputs (e.g., materials damages). The economics of the effects of air pollution upon the supply of worker effort and participation has apparently not been studied at all.

The analytical perspective that studies of this sort might adopt is exemplified at least in part by the perspective this author is employing in a U.S. EPA-funded study of the impact of air pollution upon the work performance of citrus pickers in southern California. In this study, the individual citrus picker is viewed as a contractor who sells his labor services in response to various combinations of piece-work wage rate offers and expected picking and environmental conditions. The product the picker is selling is the number of boxes of fruit he picks within a given time interval. His returns are determined by his wage per box of fruit picked and the relative ease of picking the fruit. It is thus presumed that the worker attaches utility to his working conditions as well as his additional income and is willing to substitute one for the other. The grove owner is aware of this. He thus produces a primary output (fruit) that he sells in the market and a set of working conditions that he offers his pickers. The grower's problem is then to choose a combination of working conditions and fruit output, while the picker's problem is to choose a combination of working conditions and piece-work wage rates.

This analytical perspective coincides with the fundamental view of voluntary coordinated production presented in Thompson (1968), Alchian and Demsetz (1972), and Crocker (1973). It can be empirically implemented by means of procedures similar to those set forth in Rosen (1974). It seems desirable to invest some research effort in additional attempts to assess these effects, because there is no existing information dealing with the impact of air pollution upon labor supply and productivity, because an analytical framework and empirical observations are readily available, and because it is not implausible that the effects in question may be substantial. It is likely that the analytical framework and perhaps some of the empirical results will be transferable to labor productivity situations involving other environmental pollutants in the work place.

4. Environmental Quality Indices

In the early 1970's, there was some hope that useful indices could be constructed capable of conveying in capsule form some information about changes in benefits of improvements in environmental quality. Enthusiasm for the possibilities of constructing these indices was evident in the 1972 Annual Report of the Council on Environmental Quality, though subsequent reports have been noticeably less sanguine about these prospects.

Attempts to construct such indices have viewed changes in ambient pollutant concentrations as being nearly synonymous with changes in air pollution control benefits. Factors indicative of social valuations have entered only as more-or-less arbitrarily chosen weights to be attached to the changes in ambient concentrations of each pollutant of concern. These weights were typically based upon the Federal primary or secondary air quality standards, and a great many facets of the economic benefits of air pollution control were neglected.

To improve upon earlier attempts to construct useful indices of changes in the benefits of air pollution control, one needs to initiate the exercise from within an analytical economic framework rather than a physical taxonomy. In particular, the quality of the atmosphere must be viewed as a factor of production that, in combination with other factors, influences objects such as states of health that individuals value. Thus, for example, one aspect of the "quality" index of an urban atmosphere might be the difference in some morbidity characteristic in the present relative to some predetermined standard atmosphere.

Even if dollar values cannot always be attached to the particular object of preference, a great deal more information about benefits would be conveyed in this manner than with a simplistic recitation of ambient pollutant concentrations. Moreover, in order to construct a useful index, one need not have near-complete information on the relation connecting air pollution to the object of preference. In many cases, the accumulated wisdom and knowledge of researchers will permit the assignment of probabilities to various possible forms of the relation. These probabilities can then be aggregated to form the desired index, in accordance with well-known principles of the mathematical theory of probability.

5. Form of Benefit Functions

Economic theory provides few clues to the functional forms appropriate to the specification of economic relationships. Benefit functions have been estimated using a variety of specifications without noticeable concern as to the appropriateness of the functional form chosen. However, the choice of specifications affects one's estimates of the characteristics of the benefits function and therefore the calculated benefits from a change in ambient air pollutant levels. This has been recognized by Nelson (1975) in his employment of the household production function approach. Recent references on the problem of choosing functional forms include Dhrymes et al. (1972), Pesaren (1974), Ramsey (1974), and Schmidt (1974).

6. Interview Studies

The major reason for distrust of interview studies in which the interviewee is asked his willingness to pay for alternative ambient air quality states is that he has an incentive to bias his responses depending on how he anticipates the information will be used. Although statements of total willingness to pay for given levels of air pollution control may be biased, the differences in total willingnesses to pay for various levels may be reasonably accurate representations of marginal willingnesses to pay. It is, of course, the latter that is of primary importance for decision making purposes.

It is difficult to conceive of any way other than interview studies of valuing such amorphous facets of air pollution problems as visibility and other aesthetic effects (Randall et al., 1974; Krutilla and Fisher, 1974). Moreover, certain techniques for eliciting truthful responses about preference orderings have recently been developed by economists studying the demand for public goods (Clarke, 1971; Bohm, 1972). Although most of these techniques have not been empirically implemented, it seems worthwhile to study their possible empirical biases in some detail, if only to ascertain whether the present state-of-the-art really justifies the continued viewing with great skepticism of interview studies.

7. Studies of Agricultural Damages

Studies of air pollution damages to agricultural crops have focused upon the physical response, i.e., the influence of air pollution upon the physical magnitude of output and the mixes and magnitudes of physical inputs that are adopted. The calculated economic damages reported in agricultural damage studies typically assume that changes in these outputs and inputs have no influence whatsoever upon the unit price of the output or the unit costs of the inputs. The determination of these price effects requires the construction of a detailed econometric model of the agricultural market in question. Models of agricultural markets that are capable of capturing these price effects are generally available, and should be applied to air pollution studies.

8. Testing for Exclusion of Variables

Many of the investigators of property value and health effects studies have had to rummage through large data files involving numbers of structural, neighborhood, household, and personal attributes that, given the discriminatory abilities of the models employed, could plausibly be determinants of property values or health effects. Generally, no prestated strategy performed in a reproducible way has been used to choose the set of explanatory variables for which estimated parameters are finally reported. This is true in spite of the widely known fact that the exclusion of a relevant variable from an expression to be estimated will usually bias the estimated parameters of the included variables.

In order to ameliorate this problem, some writers have employed factor analysis. However, the economic meaning of the grouped variable then obtained is typically unknown. A program called AID (Automatic Interaction Detector) by Sonquist et al. (1973) simulates the prestated, if complex, strategy followed by a good researcher in searching for the explanatory variables that increase his power to account for the variance of a dependent variable. Using this program, it should be possible to substantially reduce the likelihood that a relevant explanatory variable is inadvertently excluded while simultaneously avoiding the construction of economically meaningless grouped variables.

E. STATUS AND PROSPECTS OF BENEFITS ASSESSMENT

This closing section reviews the current state of the art in assessment of air pollution control benefits and weighs its role and prospects in policy decisions. An increased allocation of resources is advocated for implementation of a directed and meaningful research program.

1. Status and Role of Benefits Assessment

In my opinion, the current state-of-the-art in assessment of the benefits of air pollution control is rather feeble. Entire classes of benefits possibilities stemming from amelioration of uncertainty and inter-temporal externalities are nearly completely neglected on both analytical and empirical terms. Static, nonpecuniary externalities have monopolized empirical attention. However, the results from studies devoted to this class of benefits have rarely been stated in a form most useful to the decision maker. That is, no probabilities have been attached to the alternative results. Because of the frequent absence of an explicit analytical framework grounded in economic theory, the economic meaning of many of these results is a matter of guesswork in any case. Given these problems, attempts to establish aggregate national estimates of the benefits of air pollution control are subject to enormous error.

The prospects for attaining national damage estimates are by no means entirely bleak, however. New analytical approaches and empirical techniques have become available that are soundly based in economic theory, are susceptible to empirical treatment, and for which data are already available or at least are readily collected. The application of these approaches and the empirical techniques necessary for their implementation for estimation of the benefits of air pollution control is feasible. Moreover, from the perspective of decision makers, the encouragement of these approaches and techniques should be worthwhile and is likely to become increasingly so.

It is axiomatic that the set of obligations faced by a public decision maker will usually differ greatly from the obligations faced by the sufferers from and perpetrators of air pollution, if only because the public decision maker is unable to appropriate directly any pecuniary benefits his decisions may cause. Thus the benefits of one activity relative to another will differ between the public decision maker and the air pollution sufferers and perpetrators. Therefore, if the public decision maker is to act as the embodiment of the sufferers and perpetrators by choosing the set of activities maximizing the combined value of the air resource to sufferers and perpetrators, it must itself face a price structure, given its own obligations, that will cause it to choose this set of activities. Use without complementary information of benefits assessments and associated cost assessments (that is, the price structure relevant to sufferers and perpetrators) may cause the public decision maker to choose an inefficient set of activities. Nevertheless, benefits assessment can be of great assistance in choosing the set of activities that, given the decision maker's obligations, constitute the economically efficient set of activities. The reasons are several.

First, the availability of sound benefits assessment can help set the decision maker's thinking straight. It makes it more costly for him to set a policy course that entirely neglects the pervasiveness of economic scarcity. Second, it enhances the development of a framework in which, as additional information is accumulated, more sophisticated and knowledgeable analysts can insert their own results and probability estimates to make more informed judgments. Third, it also permits the decision maker to insert his own results and probability estimates about air pollution control benefits. Fourth, it helps the decision maker see which questions for possible further investigation are of greatest impact in terms of changing policy choices. Fifth, if put together in a coherent analysis, it may at least point toward a class of desirable policy decisions and, on occasion, even a unique decision. Finally, the chances of the decision maker erring are likely to increase progressively through time if he disregards benefits assessments in his policy choices.

The last of the above arguments for public decision making giving more attention to benefits assessments rests on two considerations that have received a good deal of attention in the recent economics literature which has been synthesized by Krutilla and Fisher, 1975. The first of these considerations is that for a great number of people man-made environments do not substitute for natural environments over a quite wide range of availability of the latter. This range of nonsubstitutability or very low substitutability appears to increase with respect to realistic increases in per capita incomes. Furthermore, there are strong theoretical grounds for arguing that improvements in man's production technologies tend to enhance the supply of man-made goods and services while leaving the supply of goods and services produced by natural environments either unaffected or causing this supply to decline. The implication is again that the value of natural environments relative to man-made environments will tend to increase over time. A casual approach by public decision makers to benefits assessment can therefore become increasingly costly to the citizenry whose welfare the decision maker is supposed to be enhancing.

2. The U.S. EPA Program

In view of its potentially important role in establishment of environmental policy, one is moved to ask why benefits assessment research has not progressed farther in the recent past and why, if appearances are real, it has now been accorded a rather low research priority by U.S. EPA. Several plausible reasons exist for this state of affairs.

It's possible that skepticism by natural scientists about the discipline of economics has been a factor in U.S. EPA's reluctance to use economic models for benefits assessment while amicably greeting models from biomedicine, meteorology, and other areas that provide estimates with larger errors and greater sensitivity to extreme events than do economic models. Such a situation is unlikely to be ameliorated unless someone who understands economic analysis is provided equal opportunity with natural scientists to formulate U.S. EPA's research programs.

An additional factor that may have contributed to the relative lack of U.S. EPA concern about benefits assessment is the Clean Air Act itself. Of the many objects of preference individuals have, this Act can readily be read as elevating health to a place where little else can be considered in research activities or control policies until the public health is fully protected [see Sections 103(a) and 109 (a)]. Consideration of economic considerations is relegated to vague statements about the public welfare while explicit reference to epidemiology, toxicology, etc. is made. The desirability of the vague statements and the explicit references is not at issue. The point is that the Act is probably interpreted as saying that economic considerations are, at best, of secondary importance in air pollution problems.

This, of course, is not true, for the Act nowhere inhibits economic considerations with respect to whether to set, for example, an ambient standard or a source performance standard, or whether or not to set any standard whatsoever. It is here that benefits assessment can be of greatest value to decision makers. Nevertheless, research on the economics of air pollution control benefits has not yet produced a set of results regarded to be sufficiently compelling to warrant their serious use in air pollution control planning.

U.S. EPA appears to have lacked a successful research strategy in the economics of air pollution control benefits. The two main features of any existing strategy seem to have had speed of acquisition of results and accumulation of piecemeal, uncoordinated, isolated studies by individual researchers. The first of these features implies a failure to recognize that any serious analytical effort takes a fair amount of time and that crash programs are not likely to be successful. As someone has pointed out, a crash research program bears at least a family resemblance to an effort to have a baby born in one month by getting nine women pregnant. U.S. EPA's efforts in biomedical and technological research have perhaps followed more normal and acceptable fertilization procedures.

The result of the piecemeal feature has meant that a random collection of studies, highly variable in quality and significance, has been produced. These isolated efforts do not serve effectively as building blocks to be put together in a cumulative fashion for subsequent studies, nor are they particularly useful for decision making purposes.

In fact, such an effort can fruitfully be viewed as an investment-production process characterized by considerable uncertainty and stochastic elements (i.e., surprises, disappointments, and errors). Naturally, in this investment-production process, as high a return as possible is desired. However, that which constitutes a payoff and the means by which this payoff is to be maximized, cannot be adequately characterized, without knowing the objectives of those who will use any information that is generated. Otherwise, one can't know whether the research emphasis given various regions, pollutants, sufferer classes, and analytical and empirical refinements correspond to those most useful to decision makers.

In the absence of knowledge of explicit objectives, my major research recommendation is that the U.S. EPA concern with aggregate national control benefits should, for the moment, be limited to development of a plan for microeconomic benefits research that is explicitly tied to economic theory and which will permit consistent aggregation within a framework accounting for the intrinsic uncertainty of all benefits estimates. My views as to what constitutes the possibly effective long- and short-term components of this strategy have been set forth earlier in this paper.

F. REFERENCES AND BIBLIOGRAPHY

Acton, J. P., "Nonmonetary Factors in the Demand for Medical Services: Some Empirical Evidence," Journal of Political Economy 83:595-614, June 1975.

Alchian, A. A., and H. Demsetz, "Production, Information Costs, and Economic Organization," The American Economic Review 62:777-795, December 1972.

Anderson, R. J., Jr., and T. D. Crocker, "The Economics of Air Pollution: A Literature Assessment," in P. B. Downing, ed., Air Pollution and the Social Sciences, Praeger Publishers, New York, 133-166, 1971.

Arrow, K. J., and F. Hahn, General Competitive Analysis, Holden-Day, Inc., San Francisco, 1971.

Bohm, P., "Estimating Demand for Public Goods: An Experiment," European Economic Review 3, June 1972.

Brown, R. S., and S. Enke, "Economic Worth of Preventing Death at Different Ages in Developing Countries," Journal of Biosocial Science 4:299-313, July 1972.

Clarke, E. H., "An Approach to the Demand for Public Goods," Public Choice 9:84-93, 1971.

Cobb, F. W., et al., "Photochemical Oxidant Injury and Bark Beetle Infestation of Ponderosa Pine, II, Effect of Injury upon Physical Properties of Oleoresin, Moisture Content, and Phloem Thickness," Hilgardia 39:147-149, 1968.

Council on Environmental Quality, Third Annual Report, Washington, D.C., August 1972.

Crocker, T. D., Urban Air Pollution Damage Functions: Theory and Measurement, U.S. Environmental Protection Agency, Office of Air Programs, June 1971.

Crocker, T. D., "Climate and Household Expenditures," in T. A. Ferrar, ed., Climate and the Urban Economy, Wiley Interscience, New York (forthcoming).

Crocker, T. D., "Contractual Choice," Natural Resources Journal 13:561-577, October 1973.

Crocker, T. D., "Benefit-Cost Analyses of Benefit-Cost Analysis," in H. M. Peskin and E. P. Seskin, eds., Cost-Benefit Analysis and Water Pollution Policy, The Urban Institute, Washington, D.C., 341-360, 1975.

Davis, K., and L. Russell, "The Substitution of Hospital Care for Inpatient Care," Review of Economics and Statistics 54:109-120, May 1976.

Dhrymes, P. J., et al., "Criteria for Evaluation of Econometric Models," Annals of Economic and Social Measurement 1/3:291-324, 1972.

Fama, E. F., and J. D. MacBeth, "Risk, Return, and Equilibrium: Empirical Tests," Journal of Political Economy 81:607-636, 1973.

Feldstein, M. S., "An Economic Model of the Medicare System," Quarterly Journal of Economics 85:1-20, February 1976.

Fisher, F. M., and K. Shell, The Economic Theory of Price Indices, Academic Press, New York, 1972.

Freeman, A. M. III, "On Estimating Air Pollution Control Benefits from Land Value Studies," Journal of Environmental Economics and Management 1:74-83, May 1974.

Green, H. A. J., Aggregation in Economic Analysis: An Introductory Survey, Princeton Univ. Press, 1964.

Grossman, G., The Demand for Health: A Theoretical and Empirical Investigation, Columbia University Press, 1972.

Grossman, M., "On the Concept of Health Capital and the Demand for Health," Journal of Political Economy 80, March/April 1972.

Jaksch, J. A., Outpatient Medical Costs Related to Air Pollution in the Portland-Vancouver Area, Department of Agricultural Economics, Oregon State University, Corvallis, Unpublished Ph.D. Dissertation, 1973.

Krutilla, J. V., and A. C. Fisher, The Economics of Natural Environments, The Johns Hopkins Press, Baltimore, 1975.

Lave, L., and E. Seskin, "Air Pollution and Human Health," Science 169:723-733, 21 August 1970.

Lichtenstein, S., "Bases for Preferences Among Three Outcome Bets," Journal of Experimental Psychology 69:162-169, 1965.

Lind, R. C., "Spatial Equilibrium, Rents, and Public Program Benefits," Quarterly Journal of Economics 87:188-207, May 1973.

Marschak, J., and R. Radner, Economic Theory of Teams, Yale University Press, 1972.

Marshall, A., Principles of Economics, 8th edition, McMillan and Co., London, 1961.

Mercer, L. J., and W. D. Morgan, Reassessment of the Cross-Florida Barge Canal: A Probability Approach, Department of Economics, University of California, Santa Barbara, June 1975.

Miller, P. R., et al., "Photochemical Oxidant Injury and Bark Beetle (Coleoptera scolytidae) Infestation of Ponderosa Pine III, Effect of Injury upon Oleoresin Composition, Phloem, Carbohydrates, and Phloem pH," Hilgardia 39:135-140, 1968.

Mohring, H., "Alternative Welfare Gain and Loss Measures," Western Economic Journal 9:349-368, December 1971.

National Academy of Sciences, Coordinating Committee on Air Quality Studies, "The Effect of Uncertainty on Project Evaluation and Design," Air Quality and Automobile Emission Control, Vol. 4, The Costs and Benefits of Automobile Emission Control, prepared for Committee on Public Works, U.S. Senate, Washington, D.C., 427-470, September 1974.

Nelson, J., Residential Choice, Hedonic Prices, and the Demand for Urban Air Quality, a paper presented at the Third World of Congress of the Econometric Society, Toronto, Canada, 16-20 August 1975.

Niskanen, W. A., and S. H. Hanke, On the Use of Land Values in Benefit-Cost Analysis, Department of Economics, University of California, Berkeley (undated).

Oi, W., "An Essay on Workman's Compensation and Industrial Safety," Supplemental Studies for the National Commission on State Workman's Compensation Laws, Washington, D.C., 41-106, 1975.

Pesaran, M. H., "On the General Problem of Model Selection," The Review of Economic Studies 41, April 1974.

Peskin, H. M., Accounting for the Environment: A Progress Report, paper prepared for the Second National Symposium on Corporate Social Policy, Chicago, Illinois, 3-5 October, 1974.

Phelps, C. E., and J. Newhouse, "Coinsurance, the Price of Time, and the Demand for Medical Services," Review of Economics and Statistics 56:334-342, August 1974.

Pollak, R. A., and M. L. Wachter, "The Relevance of the Household Production Function and Its Implications for the Allocation of Time," Journal of Political Economy 83:255-278, April 1975.

Pouliquen, L. Y., Risk Analysis in Project Appraisal, The Johns Hopkins Press, Baltimore, 1970.

Pruitt, D. C., "Pattern and Level of Risk Taking in Gambling Decisions," Psychological Review 69:187-201, 1962.

Ramsey, J. B., "Classical Model Selection Through Specification Error Tests," in P. Zarembka, ed., *Frontiers of Econometrics*, New York: Academic Press, New York, 1974.

Randall, A., *et al*., "Benefits of Abating Aesthetic Environmental Damage," *Agric. Exp. Sta. Bull. 618*, New Mexico State University, Las Cruces, New Mexico, 1974.

Rosen, S., "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition," *Journal of Political Economy* *82*:34-56, January/February 1974.

Rosett, R. N., and L. Huang, "The Effects of Health Insurance on the Demand for Medical Care," *Journal of Political Economy* *81*: 281-305, March/April 1973.

Schmidt, P., "Choosing Among Alternative Linear Regression Models," *Atlantic Economic Journal* *1*, July 1974.

Sonquist, J. A., et al., *Searching for Structure*, Institute for Social Research, University of Michigan, 1973.

Stark, R. W., *et al*., "Photochemical Oxidant Injury and Bark Beetle Infestation of Ponderosa Pine, I, Incidence of Bark Beetle Infestation of Injured Trees," *Hilgardia* *39*:121-126, 1968.

Thompson, E. A., "The Perfectly Competitive Production of Collective Goods," *Review of Economics and Statistics* *50*:1-12, February 1968.

U.S. Environmental Protection Agency, *The Clean Air Act, As Amended June 1974*, Washington, D.C., 1974.

ATTACHMENT. AN ILLUSTRATION OF SOME ISSUES IN BENEFITS ASSESSMENT

This attachment seeks to illustrate the application of the foregoing discussion to a real world problem by analyzing the benefits accruing from controlling a single class of pollutants in a specific locality.

1. Introduction

Conventional microeconomic theory constructs an extremely general conceptualization of the consumer or producer decision making process. For example, in the case of the consumer, households are assumed to allocate their budgets so as to maximize the utility they derive from the purchase and consumption of goods and services subject to the constraints imposed by the resources to which they have access as well as the prices of the commodities available to them. Since the conceptualization is extremely general and, therefore, abstract, many issues that are of importance to particular applications are assumed to be irrelevant in order to focus attention on the key principles governing consumer choice.

However, once the framework is applied to a specific set of decisions, such as those involving the behavior of sufferers from air pollution, then an array of details must be reviewed. These details are indeed relevant to the usefulness of the models on which the decisions are to be based and to the behavioral outcomes that these models would predict. Inclusion of these details considerably complicates the analytic, and even more the econometric treatment of the benefits of air pollution control; but outright omission in the interests of tractability may grossly misrepresent the phenomena involved. By focusing upon a particular type of market in an identifiable locale, the reader should become more sensitive to the most important of the aforementioned details and the difficulties one faces in trying to account for them.

The natural framework of analysis for the economist is the market, the interaction of buyers and sellers. Air pollution affects behavior in a wide variety of markets, each of which has its own unique structure. As used here, the term "markets" is meant to apply to all air pollution control benefits studies employing market-established prices or some surrogate as a means of establishing benefit assessments. The term is thus meant to encompass each of the methods of assessment (technical coefficients, market, opinion surveys, litegation, political expressions, and Delphi) that Waddell (1974) distinguished. The presumption is that a model, whether implicit or explicit, of a market is present when any one of these methods is employed in a given situation. That is, at its roots, any use of one of these methods involves some perspective of the structure of buyer and seller interaction.

The benefits of air pollution control in the particular market to be discussed are probably trivial relative to the benefits in markets such as human health and life, materials, housing, and assorted other buyer and seller interactions in which air pollution is thought to have a significant role. Nevertheless, this case is very illustrative for each of its peculiarities are present in one or more of the markets that are typically studied for purposes of estimating the benefits of air pollution control. In addition, this case illustrates the difficulties encountered in analyzing the recreation benefits of water pollution control which have been mentioned in the other papers of the report. Recreation benefits are, it is frequently asserted, a major portion of the total benefits of water pollution control.

2. Presentation of the Problem

The San Bernardino Mountains of Southern California serve as one of the primary outdoor recreational resources available to the approximately 11 million people of the Los Angeles Basin. On the slopes of these frequently extremely steep mountains grows a highly varied set of plant communities ranging from hot desert to sub-artic. The lower portions are dominated by a fairly dense coniferous forest consisting primarily of ponderosa pine and white fir. Here are found the most heavily used outdoor recreational facilities, including hiking trails, campgrounds, lakes, small mostly intermittent streams, and arrays of publicly and privately provided outdoor recreational amenities, such as cabins and restaurants.

Most users of these facilities would probably agree that the ponderosa pine, an esthetically pleasing tree that is large, tall, shady, and straight-stemmed, contributes significantly to their outdoor recreational experiences. Recently, however, a relation has been found between ozone, or ambient oxidants, and susceptibility of this pine to attack by insects. It is thought that the combined action of insects and pollutants results in higher rates of needle drop and death than the action of insects alone. (Miller et al., 1968; Stark et al., 1968; Cobb and Stark, 1970).

Let us presume that the biological relationship between photochemical oxidants and ponderosa pine morbidity and mortality has been reasonably well established. The problem facing the economist, then, is to tie to this biological relation a welfare measure that simultaneously registers the values of outdoor recreationists and is meaningful to air pollution control decision makers. That is, the economist's task is to assess the value outdoor recreationists place upon the presence of healthy ponderosa pine.

This task is not easy, since neither air pollution control, the services of ponderosa pine forests to outdoor recreation experiences, nor recreation experiences themselves are, for the most part, exchanged in organized, explicit markets permitting direct observation of the relative values households attach to such goods and services. One must therefore infer the relative values households attach to ponderosa pine in various states of health from observations on the rates at which these households voluntarily substitute one state for another and the market values of the resources they expend in performing these substitutions.

However, in order to make these inferences, all other factors that influence the voluntary rate of substitution must be accounted for. This accounting requires the construction of a model of the nature of buyer and seller interaction in outdoor recreation. Some of the structural features of the outdoor recreational market that, ideally, should be integrated into this model are described below. With a bit of reflection, the reader will recognize that similar features (in kind, if not in degree) are to be found in many of the actual markets studied in the past to ascertain the benefits of air pollution control. For example, whenever the term "outdoor recreation" appears, the term "housing" or "state of health" would generally serve just as well. (Vars and Sorenson, 1975).

3. Multi-Dimensional Heterogeneity

The sites a household considers in planning its outdoor recreational activities are heterogeneous rather than homogeneous. That is, they exhibit great differences in a number of different dimensions to which the household typically attaches value. Differences in the physical recreation sites themselves are obvious enough. For example, these differences may be manifested in size, number of campsites, topography, forest type and condition, and other attributes.

But an outdoor recreational site embodies more than the physical site itself. It is a composite consisting of the site and its accessibility with respect to alternative recreational sites and the household's residence. Accessibility of sites differs greatly in terms of the pecuniary and temporal outlays required and in terms of the quality of transport mode and route. Moreover, outdoor recreational sites, as well as the transport modes and routes that provide access differ greatly in the cultural backgrounds of the people who frequent them, the assortment of privately owned goods available, the quality and quantity of common property and publicly owned goods provided, and congestion.

The state of affairs described above is really not altogether unusual in applied economic analysis. Just about any entity a household values can be viewed as a composite of several attributes. Frequently, these components will differ substantially among various sellers and among various buyers. Economists nevertheless habitually aggregate these heterogeneous entities into units of analysis they term goods, industries, etc. The aggregate unit of analysis is usually probably a good approximation of the most informative unit for the purpose at hand. However, in the economic analysis of outdoor recreation markets, the question of the most informative units of anlaysis must be approached with a good deal more caution than is customary. The reasons are several.

First, at least to the casual observer, households appear to exhibit great differences in the utility they derive from outdoor recreation. They differ greatly in the value they attach to any form whatsoever of outdoor recreation, as well as in the relative importance they associate with various forms of outdoor recreation. In addition, for any particular form (e.g., viewing scenery), they differ in their preferences for the various components of the form. All this implies that the differences observed among outdoor recreational sites influence the market. To some extent, particularly in the case of accessibility, the observed differences might not be matters of chance but are instead demand-induced.

Second, the consumer and the producer are able to exercise much less discretion as to the components of the commodity in the case of outdoor recreation. The household that consumes outdoor recreation experiences has substantial discretion with respect to the set of alternative recreational opportunities, but, once the choice is made, many subsequent events are outside its control. For example, when arriving in the mountains, the household is unable to control the congestion at a site it does not own. Therefore, it is unable to control the extent of deterioration in the quality of services it had expected to obtain at the site. Since this can greatly affect the utility of recreation and typically occurs without the direct intermediation of the market, there exists a large potential for substantial externalities in outdoor recreational markets.

Third, from the perspective of the individual household, the great variety of outdoor recreational sites available in Southern California means that they are imperfect substitutes for one another. Any fairly large collection of sites is likely to exhibit a range of substitutive relations extending from rather close to nonexistent. Is the beach a close substitute for the mountains? In addition, given the near impossibility of untying the packages into which the components of most sites are bound and, given the limited number of sites the household is likely to consider, there may exist a major difference in the degree of substitutability that pairs of households assign to the same pair of sites. This implies that a single outdoor recreation market does not exist. Instead, there seems to be a set of markets that are more or less related to one another.

One serious consequence of this market segmentation is that the supply and demand relations that constitute each market segment can behave in different fashions across segments. Price elasticity of demand for a particular activity may be high in one segment and low in another; one segment may have excess demand for a certain activity, while another may have excess supply. All this implies that prices, whether implicit or explicit, may vary across the segments. Moreover, an exogenous change that impacts forecefully on one segment may have no impact whatsoever in another segment.

This segmentation of the outdoor recreation market is nourished by the high cost for households of information about market conditions. Information is clearly an important factor in household decisions when one recognizes the great variety of outdoor recreational opportunities and the differences in preferences among households for these opportunities. However, it seems unlikely that households can afford to survey all or even a major part of their potential opportunities. Instead, they limit their search to some portion, a delineation probably based on various rules of thumb reflecting prevailing knowledge about opportunities that are good substitutes for one another.

4. Costs of Market Participation

To a perhaps greater extent than for many other commodities, the act of participation in the various segments of the outdoor recreation market is costly. For several reasons, the cost of the act of participation tends to harden the discrepancies in prices across market segments. First, as previously noted, since heterogeneity in available outdoor recreational opportunities is pervasive and considerable and tastes regarding these differences are quite important, substantial search by a household may be required to assure a satisfactory recreational experience.

Second, the consumption of outdoor recreation generally requires that the household remove itself from its permanent residence and selectively travel to one or more sites at which the chosen combination of the components of the recreation package afe thought to exist. Outdoor recreation does not have the portability of the typical commodity. Since the commodity cannot be carried from one location to another, the household experiences pecuniary and temporal costs in overcoming the distance necessary to match household to site. Third, even after the household's search has been terminated and the distance to the site overcome, actual participation usually requires the purchase of complementary inputs.

These costs imply that the prospective gains from becoming an active participant in the market may have to be quite substantial in order to warrant such participation. The values of those who do not participate are not registered in the market. The prospective gains the household perceives from participation can arise from changes in the household's preferences with respect to different combinations of outdoor recreation packages and with respect to recreational versus non-recreational commodities. They can also arise from changes in the components and in the implicit and explicit prices of the different packages available on the market.

Barring changes of these sorts, the high cost of market participation suggests that participation is likely to be intermittent rather than continuous for most households. This, in turn, implies that the set of households one observes participating, and thus determining the outcome of market transactions in any fairly short time period, might not be representative of the entire population of households.

5. Institutional and Temporal Constraints

Apart from the problems that multi-dimensional heterogeneity, information, and the costs of market participation introduce, the outdoor recreational market bears little semblance to a perfectly free market. Indeed, the outdoor recreational market in Southern California has been subjected to a number of public institutional controls, including assorted health and safety regulation, non-price rationing, such as queuing, and zoning regulations intended to inhibit congestion. In effect, these controls reduce the domain over which the market is able to exercise discretion in adjusting to changing situations.

Although the reductions in negative externalities which these controls permit may well exceed any losses in efficiency which the controls engender, such losses are nevertheless undoubtedly present.

They involve the losses present when every household is forced to consume and/or produce in more or less the same manner and the flexibility that is lost when the only parameter subject to occasional adjustment is the value of the regulation. Moreover, to the extent they reduce substitutability among sites, the controls intensify whatever tendency toward market segmentation already exists.

The constraints the household faces while recreating are not only budgetary and those publicly designed to shape its activities. Most households are unable to allocate their time in any arbitrarily desired way. Instead, the household's free time for outdoor recreation is structured and limited by inalterable work schedules. In the case of family units, work and education schedules may interact, so as to curtail family recreational time futther. Even individuals who are self-employed are constrained to the extent they must interact with other individuals and businesses.

6. Conclusion

All of the issues discussed above are relevant to the assessment of effects that changes in the health state of the ponderosa pine forest have upon the choice behavior of outdoor recreationists in Southern California. The discussion is, in fact, germane to most, if not all, markets that are studied to assess the benefits of air pollution control. Nevertheless, a model capable of capturing the full impact of the multi-dimensional heterogeneity, cost of information and market participation, and institutional and temporal constraints of the outdoor recreation market upon the household's decision problem would indeed be unusual. In any model that is to have real application, the treatment of many and sometimes most of the issues raised above must of necessity be conjectural. That is, in his applications of a model of beneficiary behavior, the investigator must be willing to take a subset of these issues as already settled for the application in question. Both the limited availability of suitable data and the limited abilities of investigators in model construction dictate the failure to comprehend in each instance the range of these issues.

Most fundamentally, in any attempt at benefit assessment one must examine the role the assessment is to have in the decision making process. In effect, one must know with some precision the criteria to be used to evaluate the assessment as well as the objectives of the assessment effort. Such knowledge permits the investigator to isolate those facets and issues with significant implications for decisions from the less important ones. (Crocker, 1975).

IV. BENEFITS OF WATER POLLUTION CONTROL

Joe B. Stevens
Oregon State University

A. INTRODUCTION

Despite the richness of the literature in applied welfare economics and benefit-cost analysis, there is currently very little concrete knowledge of the extent of economic benefit which would result if water quality were brought up to state and Federal standards. The development of what knowledge does exist has been very asymmetric. Estimates of production losses, including conventional waterborne disease, are reasonably firm; unfortunately, only a small fraction of the potential benefits appear to be in these areas. The predominant share of the potential benefits appear to be in the categories of recreation, aesthetic uses, and option demands, where the methodologies for simulating consumers' willingness to pay for quality improvements are much less well developed.

The lack of adequate, generalizable behavioral relationships between water quality and consumer behavior, and hence, willingness to pay for quality improvements, is thus the predominant problem in assessing pollution control benefits. There is simply inadequate knowledge concerning why people "consume" leisure-type environmental activities, and especially how changes in water quality (objective and/or perceived) affect these consumption activities. Some creditable work has been done in estimating recreation benefits from pollution control in small areas, but extrapolation of these studies to national aggregates is not currently possible with any degree of precision. The monetization of aesthetic and option demand is, at present, even less well developed than for active recreation uses.

Increased precision in the measurement of consumption benefits (recreation, aesthetics, option demand) will come slowly and probably fortuitously in the absence of an expanded U.S. EPA role in benefit estimation. This is particularly true for the evaluation of efficiency at an aggregate level. Decentralized academic researchers do not have an incentive system which encourages them to derive "premature" estimates of national benefits or to structure their partial equilibria analyses to facilitate this derivation by U.S. EPA or other institutions. Asking even the best consulting firm to extrapolate existing partial analyses when these were not designed to be extrapolated is a hopeless strategy.

Thus, U.S. EPA should assume an expanded role in designing and funding high-quality analyses of consumption benefits, where these analyses have the express objective of being extrapolated to national levels. As a complement to this activity, a basic commitment should be made by EPA to establish a long-term "behavioral monitoring system" analogous to that established by the U.S. Geological Survey for assessing water quality. Common socio-economic and physical data sets need to be maintained over time at sites where water quality changes are, in fact, occurring. The rationale is that a much more adequate knowledge of behavioral response with respect to water quality changes must be established before the efficiency of water quality enhancement can be assessed with any substantial precision.

B. CONCEPTUAL FOUNDATIONS

This section is intended only as an overview of the welfare economic foundations of benefit estimation in water pollution control, since several other sources treat this essential topic in much more detail. It identifies and synthesizes the implications of general and specific problems affecting current benefit estimates, by category of damage (e.g., health, recreation), and offers a set of suggestions for improving the quality of future estimates.

1. Role of Benefit-Cost Analysis

Historically, benefit-cost analysis has been a valuable tool for analyzing the economic worthwhileness of alternative public policies. Although its origin can be traced to legislative mandates (e.g., the Flood Control Act of 1936), rather than theoretical modeling, substantial theoretical and empirical literature on benefit-cost analysis now exists. The relevance of this literature to the analysis of benefits and costs of water pollution policy has been documented in a 1973 EPA Symposium, the proceedings of which are now in print and available to administrators and researchers (Peskin and Seskin, 1975).

A particular policy can be supported by two antagonists, each of whom views the policy as contributing to a different objective. Also, it is uncommon in the political world that the real objectives of the policy's promoters will be explicitly stated, if in fact, the promoters are actually capable of articulating these objectives. Indeed, the "muddling through" or "disjointed incremental" approach to public policy (Lindblom, 1959) rests largely on the notion that agreement on "means" (i.e., policies) is primary, and that agreement on "ends" (i.e., objectives) is secondary and perhaps even unnecessary.

Benefit-cost analysis, on the other hand, presupposes that objectives do matter in the public policy process. Simply stated, the benefit-cost analyst says: "If X (or Y or Z) is your objective, then that particular objective is enhanced (or impeded) by the policy or program under consideration." The variety of objectives to which benefit-cost analysis can be addressed is limited, yet the tools are powerful if economic efficiency is a relevant objective.

Three possible objectives of water pollution control policy are:

- To make efficient use of resources associated with water use
- To distribute goods and services, including those which are water-related, in an "equitable" manner
- To avoid ecological irreversibilities.

Benefit-cost analysis can make a potential contribution to each of these. However, a "state of the art" assessment of benefits from water quality improvement can most productively be focused on "national efficiency" benefits, or those which would arise from the increased value of goods and services made possible by water pollution policies. Economic science is far more advanced in contributing to this objective than to the two other objectives.

Differential incidence of benefits and costs among various people or groups may arise from different water pollution policies, and decision makers may choose to look at the problem partially or solely in this context. The state of economic science at present is inadequate to define distributional benefits in a normative sense, but instead is limited to a positive description of "who gains," "who loses," and "how much." Such descriptions are inherently useful, and should be included in any assessment of pollution control benefits and/or costs. Finally, benefit-cost analysis may be used to identify the costs of maintaining a designated water quality standard, even though the benefits from maintaining this standard may not be fully quantifiable or even perceived at this time (Krutilla, 1967).

2. Estimation of Benefits

Efficiency benefits should be defined in terms of the total value to users of increases in the national output of goods and services, where total value is defined in terms of willingness of users to pay for the additional output. Because it is often not feasible to measure individual demand functions, and hence, the willingness to pay by users, four alternative techniques for assessing these benefits have been devised.

If markets for the goods and services exist, and if the additional output does not have a significant effect on price, then market prices can be used to assess benefits. This technique will be of little value in assessing water pollution control benefits, since markets are seldom used directly to determine water quantities or qualities. Simulated markets, including demand functions, supply functions, and/or simulated market outcomes, can be used as a proxy for real markets. While the methodology for this technique is rudimentary in its development, it appears to be the only relevant technique for evaluating water quality benefits where outputs are "consumed" directly by final users. In particular, benefits to recreation and aesthetics will need to be evaluated by this method.

If the output of investment is an intermediate good, rather than one intended for final consumption, then changes in the net income of producers (or consumers), with and without pollution, may be used to reflect benefits. This method will be useful primarily for determining benefits from controlling industrial and agricultural pollution, and from reduced waterborne disease. Finally, if computation of net income changes is not feasible, the cost of the most likely alternative for attaining the same objective can be used to measure benefits. The rationale behind this method is that benefits are obtained to the extent that resources are thereby released for the creation of other goods and services.

A second category of benefits, often termed "secondary benefits," are those which might result from the use of resources which would otherwise be unemployed or underemployed (Haveman and Krutilla, 1968). In general, one would not expect to find substantially improved employment opportunities for otherwise underemployed resources, if national water quality were restored to meet Federal and state standards. The reason for this expectation is that water pollution has probably occurred gradully enough that the market has had time to re-allocate resources away from polluted areas.

3. Special Considerations

If market data could be relied on extensively for calculating benefits, care would need to be exercised to see that the markets were competitive and to account for project-induced changes in price. Under such circumstances, welfare economic theory provides a basis for asserting that prices reflect social values, provided that one accepts the prevailing income distribution as "proper". In the case of water pollution, however, much reliance in benefit evaluation must be placed on simulation of markets for non-market goods such as outdoor recreation, and calculation of net income changes. Therefore, special attention would need to be given to several criteria which relate to the internal consistency of the analysis.

Thus, inferences as to technical relationships should be at the highest "state of the art" possible within the relevant discipline. For example, the nature and extent of man-made pollution should be identified, along with marginal treatment costs for these pollutants. To the extent feasible, inferences of technical relationships should be both complete (e.g., no major omissions in types of waterborne diseases) and capable of replication.

Although direct market prices for goods and services produced by water pollution control will be of limited value in the direct assessment of benefits, some reliance must of necessity be placed on real or synthesized price data in the simulation of markets for certain goods and services. Examples include:

- Health
    - cost of medical treatment
    - value of time lost to illness
    - value of human life (present value of future earnings)
- Outdoor Recreation
    - costs of vehicle operation and travel
    - value of time spent in travel
- Production
    - marginal costs of waste treatment for various types and levels of effluents.

Use of price data where market prices are artifically set, either by imperfect competition or through public policy, should theoretically be discouraged. This is easier said than done, when one considers this varied range of contrived market outcomes:

- Health
    - restricted supply of medical personnel
- Recreation
    - OPEC policy on U.S. oil imports
    - auto prices administered by U.S. manufacturers

- Production
    - degree of price competition among suppliers of pollution control equipment
    - price support levels of farm crops lost to siltation and brackish water.

About the only reasonable expectation is that the analyst be able to identify major price imperfections where knowledge of such has been documented (e.g., farm price supports).

Where price data are relevant in the synthesis of proxies for "willingness to pay," the expected level of such prices over the lifetime of the project needs to be identified. Use of current prices such as, for example, the current cost of travel, may lead to inflated or deflated estimates of benefits, depending on what constitutes a "reasonable" long-term price expectation.

To the extent possible, the analyst should identify significant technological externalities which would be alleviated by expanded policies of water pollution control. In fact, this should form the substance of benefit calculations for improvements in water quality; these improvements would reduce the level of negative externalities to users (e.g., disease, degraded recreation opportunities). National efficiency benefits, regardless of method of calculation, should be net of pecuniary externalities (income transfers). Especially if the "net income" approach is used in benefit calculations, care should be taken that offsetting income losses are included in the analysis. Also to be questioned or excluded are windfall net rents which may accrue to fixed assets without corresponding increases in outputs of goods and services.

Where the investment project for augmenting water quality levels is expected to produce benefits extending over several years, the annual increment (or decrement) to benefits should be identified, and the present value of current and future benefit streams should be computed. Goods and services provided directly to consumers through water quality restoration are of particular concern here, in that the income elasticity of demand for different services may vary widely.

With respect to human health, research indicates that the value of the human agent has risen markedly over time (Schultz, 1968). So, too, has the demand for services to maintain the human agent, including health services. One would suspect a high and rising income elasticity, then, for avoidance of waterborne diseases. Within the category of outdoor recreation, there is reason to suspect that a substantial range exists in the income elasticities for different activities, including some "inferior" goods (Stevens, 1966). Conceptually this poses a weighting problem for assessment of benefits at the national level, where annual changes in benefits are a function of the composition of current-year benefits (by recreation activity), the expected income growth in the economy, and the income elasticities of the different activities.

These time-related changes should be identified in computing annual benefit streams. Inclusion of such calculations and breakdown of the requisite investment into installation cost and operating cost components would improve both the benefit and cost estimates, since investment projects for improving water quality would be capital-intensive and long-lived in nature.

C. GENERAL PROBLEMS

This and the following section are meant to be synoptic statements on the state-of-the-art, rather than a detailed review of empirical studies on benefit estimation.

1. State of Damage Functions

The most complete and useful review of empirical attempts to estimate water pollution control benefits is Tihansky's chapter in Peskin and Seskin (1975). To quote selectively from his conclusions: "This paper reviews an extensive compilation of major benefit studies. From an original collection of almost two hundred studies, approximately sixty are selected as contributing most to the conceptual framework and empirical insights of benefit evaluation. Of the selected studies, less than 30 percent are theoretically valid, but even fewer seem cognizant of the applicability, let alone the existence, of welfare economics ... If only recreational studies are considered, fewer than 10 percent follow from theory ... Although there is no theoretical basis for most benefit values, equally discouraging is the paucity of empirically derived damage functions. Only 20 percent of the surveyed literature derives dose-response relations from on-site data. With recreation studies, this proportion decreases to 10 percent."

Despite some allegations to the contrary, water quality data are relatively abundant. The real problem, however, is the lack of conceptually valid functional relationships between water quality parameters and associated human behavior. We need to know:

- How economic activity affects the nature and concentration of waterborne pollutants
- How the latter affects behavioral perceptions of water quality
- How this perception is translated into behavioral decisions.

Welfare economics is a useful and integrative conceptual base for benefit estimation, but existing facts often have multiple interpretations since functional relationships well-founded in theory have usually not been established. Generally speaking, welfare economics is a "non-problem" in that the accumulation of theoretical insights has far outrun the empirical implementation of the theory.

The current "state-of-the-art" in assessing water pollution control benefits strongly reflects an asymmetric development in terms of establishing such functional relationships. The reasons are partly economic and partly institutional. At an earlier stage of economic development in the U.S., the primary concern with water quality was for human health and safety. The whole historical thrust of the Public Health Service has to do with developing functional relationships between pollutants and waterborne disease. Especially with the more virulent and contagious diseases, a fairly simple behaviral response was assumed, i.e., avoidance.

As economic development progressed, natural resources were increasingly regarded as items for consumption, rather than production. At an institutional level, the Public Health Service continued to be concerned with the production of health. Elsewhere in government, water-based leisure (and most other forms of recreation) were evidently regarded as something to be done, not studied. Increased awareness of this knowledge gap led to the creation of the Outdoor Recreation Resources Review Commission and subsequent efforts elsewhere in government.

Within this set of poorly understood leisure-type phenomena are those which relate changes in water quality to changes in consumer behavior. In particular, damage functions which relate to active recreational uses of water or to more vaguely defined aesthetic uses have not been established to any substantial degree. Thus, there is inadequate knowledge of the whole set of relationships concerning why people "consume" leisure-type environmental activities, and how real and/or perceived water quality affects these consumption activities. Individual researchers have done creditable work in specifying particular water quality parameters and relating these to particular recreational activities, but there is nothing resembling a comprehensive research effort in this area.

The knowledge which does exist about behavioral responses with respect to changes in water quality is fragmentary. More crucial to the task at hand is that it deals with partial equilibria, i.e., variables which are crucial in the user's decision framework are often assumed as constants in existing analyses. In particular, most of the existing work on recreation benefits assumes a constant level of water quality in bodies of water other than the particular one being researched. In that this group of other sites probably contains some which are substitutes for the one under study, the analytical models are incompletely specified and, hence, less useful than would be desired for purposes of national aggregation. The generation of national benefit estimates implies solutions which are more general with respect to competing sites than is permitted by the current literature.

This is not surprising, in that the immediate objectives of research have usually been to measure costs and benefits of controlling specific water pollutants in specific bodies of water. Ten years ago, when estimation of recreation benefits was in its first primitive stages, it was a real challenge to perform the analysis, let alone worry about extrapolation to higher levels of aggregation. It is still generally acknowledged that consumers have a broader preference set than just the particular river or lake under study. The state-of-the-art is to assume away the influence of competing streams and how recreationists might react to more general water quality changes.

The needed knowledge of behavioral responses to changing water quality levels has not progressed to the point where reasonable extrapolation can be made with any degree of precision. Although estimates of national benefits have been derived in the past (e.g., Unger et al., 1974), these estimates are based on extrapolations which have neither a sound conceptual footing nor an underlying accumulation of coherent empirical work. Tihansky's (1975) review of such studies reveals that the bulk of water quality benefits seem generally to be in those areas where the "state-of-the-art" is least developed, particularly in the areas of recreation, aesthetics, and option demands. The same conclusion is also reached in this present paper.

2. Classification and Aggregation of Benefits

That proportion of specific pollutants which are man-made, rather than naturally occurring, and the approximate control costs for both man-made and natural pollution are often known with some degree of precision. The general tendency has been to impute average (proportional) costs to control of man-made pollutants. However, marginal costs (over and above those required to treat natural pollutants) would be a more appropriate measure. This can lead to overstating the benefits of pollution control.

There is only a weak consistency in the quality of estimates among the various benefit categories. Although health and production benefits are relatively firm, or at least susceptible to refinement through further analysis, this is not the case with consumption benefits (recreation and aesthetics). These estimates must currently rely on highly simplifying assumptions in order to utilize existing research not intended for purposes of extrapolation.

As the "state-of-the-art" develops in benefit estimation, knowledge of the growth rates of benefit streams becomes increasingly important. Technological change in the future is likely to be greater for production activities than for consumption activities. Hence, the costs of pollution to production activities (and hence, potential benefits) may be reduced over time as new technology is developed and implemented to alleviate those problems. Considering health as a "production" activity in a manner consistent with human capital theory, the per unit benefit values may rise over time as the value of human capital rises relative to that of physical capital. Some consumption benefit streams may grow and some may decline, depending in part on the income elasticity of demand for water-based services.

The decision context implicit in an assessment of national benefits and costs is one of aggregate efficiency in water resource use. The broad question is "Do the national benefits of cleaning up our water outweigh the costs?" In reality, the issue of whether or not this is the most productive question to be asked must be faced. Obviously, a good answer to the larger question would be immensely valuable to policy makers.

On the other hand, asking the broad question about an overall benefit-cost ratio may conceal the fact that there are a host of individual benefit-cost ratios (some high, some low) for cleaning up specific pollutants and for cleaning up or protecting specific areas. If the latter is a more appropriate decision context, then criticism of the state-of-the-art has to be mitigated to some degree. Problems with the totality of behavioral responses become less crucial, and a re-focusing on the more pressing responses is facilitated.

3. Other Problems

Even if the question of aggregate efficiency of water quality enhancement could be answered definitively, this would be sufficient information only if policy makers were interested solely in economic efficiency. This is obviously not realistic, as most policy makers are also interested in distributional issues. Whether access to goods and services would be redistributed in a progressive or regressive manner among individuals is information which is almost totally lacking in the benefits literature.

Similarly, pollution control might be progressive, if the costs of pollution, to producers now paid through higher product prices and/or utility rates, were met largely through Federal expenditures financed by a reasonably progressive tax system. On the other hand, pollution control could be regressive if the dominant beneficiaries are white-collar, urban recreationists. In addition, information is also needed on redistribution at a more aggregate level, e.g., urban versus rural states, metropolitan vs. rural areas.

It is crucial that benefits and costs be estimated for a variety of levels of water quality; this is not generally found in the literature. Such a procedure would permit marginal analysis by allowing water quality standards to be viewed as variables, rather than basic parameters to be met at all costs. In light of current concern about the high costs of meeting existing standards, the estimation of benefits and costs for a range of water quality standards becomes very crucial information.

D. SPECIFIC PROBLEMS

This section discusses problems inherent in estimation of specific benefit categories, including health, production, recreation, aesthetic, and ecological benefits, and property values.

1. Health Benefits

It would appear that extensive pre-treatment of drinking water, especially chlorination, has already greatly reduced the incidence of conventional waterborne disease outbreaks, and that further definition of benefits depends on how accurately the following can be quantified:

- Extent of such diseases as hepatitis, gastroenteritis, salmonellosis, and typhoid
- Extent to which these outbreaks can be identified as waterborne, at both current and standard levels of water quality
- Incidence of the outbreaks by morbidity and mortality classifications
- Assignment of unit values, in monetary terms, to the above categories.

Current estimates of benefits in the above categories include 1 billion (Unger, et al., 1974), 373 million (Liu, 1970), 356 million (Lackner, 1973), and 120 million (Sokoloski, 1973). While the variation in these estimates appears to be substantial, it is largely due to different working assumptions about facts and functional relationships.

Determination of the real extent of damages from conventional diseases is tractable, requiring additional time and money. Such an allocation is not of high priority, given the softness of the benefit estimates in other categories, particularly recreation and aesthetics. If such an allocation should be deemed desirable, more attention should be given to the following:

- Assignment of mortality values according to human capital theory, i.e., using expected present value of future earnings as the measure of benefit
- Recognition that both the incidence of mortality and expected lifetime earnings are age/sex/race-specific rather than constant over the population
- Recognition that health services are generally income-elastic in demand
- Recognition that costs of medical treatment have risen secularly, as compared to other commodities.

The key problem in quantifying health benefits is how best to deal with uncertain, long-term, and largely unknown water quality-health relationships, such as the presence of carcinogens and certain inorganic compounds in water. Although a consumer's perception of the importance of these events is subject to considerable emotion, misunderstanding, and lack of an informed base from which to make judgments, option value constructs should be explored within this category as well as in the categories of recreation and aesthetics. The reasons for this view are that willingness to pay can arise from desires for future as well as current consumption, option demand can be viewed as willingness to pay for future supplies of a specified good and non-carcinogenic drinking water is surely one such good.

Although it was suggested above that conversion to monetary values be based on a productivity approach (present value of future earnings), an alternative willingness-to-pay framework is now being developed in the literature (Mishan, 1971). An individual's willingness to pay to avoid contracting cancer through drinking water, for example, has an upper bound in terms of his own future productivity, if one makes the value judgment that the individual should be responsible for his own actions and liabilities. On the other hand, society may be willing, explicitly or implicitly, to expand the effective willingness to pay of an individual beyond that which he, himself, would be able to pay (i.e., his future earnings). The possibility of such revealed preferences, i.e., private and public trade-offs between the probability of death and other goods and services, need to be better understood in the context of evaluating serious health hazards with low probabilities.

2. Production Benefits

The principal specific problem within this category is the assumption that the marginal costs of water treatment due to man-made pollutants, and hence the benefits from pollution control, are equal to the prorated portion of the average cost of treatment due to both man-made and natural pollutants. If a substantial amount of natural pollution must be treated in any event, then the marginal costs of treating man-made pollution might be less (substantially or moderately) than average treatment costs. If so, using average cost data would overstate the benefits from pollution control. An extreme case is that of boiler feed water, which is usually demineralized and given tertiary treatment even in the absence of man-made pollutants. In this case, the benefits to reduction of man-made pollutants would be zero, since the marginal treatment costs are zero.

For municipal water supplies, Barker and Kramer (1973) have attributed about 39 percent of total pollution to man-made sources. For damages to household items from water supplies, Tihansky (1973) has estimated that about 17 percent of dissolved solids and hardness are due to man's activities. Also, it has been estimated (U.D. Department of Interior, 1974) that about 40 percent of total salinity in agriculture results from man-made sources.

For agricultural damages due to siltation and salinity, observed prices are often distorted by price supports for farm products. If price supports were to prevent price declines which might result from expanded farm production (due to siltation and salinity control), then use of the price support level to compute benefits would result in overestimation of benefits. This is of particular concern for desert irrigated crops such as cotton grown in the Southwest, where both salinity and siltation are production problems, and where prices are highly influenced by public policy.

3. Recreation Benefits

The inescapable conclusion is that the state-of-the-art is simply inadequate to allow generalizations of existing research to arrive at national benefits. To cite just one example, Unger *et al*. (1974) derived an estimate of 9.4 billion in recreation benefits from water pollution control. Their estimate involved extrapolation of national values from two small-area studies. One of these involved a high man/water ratio, the other involved a low ratio. Although this was an imaginative approach, the precision with which it can define true national benefits is necessarily undefined, and hence, suspect. The model is inadequately specified with respect to water quality dimensions of the two sites, and the measure of value at either site is not clearly defined.

The above study is symptomatic of the site-situation-specificity of past research on outdoor recreation benefits related to changes in water quality. Whether or not this is viewed as "good" or "bad" depends on one's views of the appropriate decision context, that is, whether or not information on *aggregate* efficiency of water pollution control is more valuable than information about the relative efficiency of improving water quality in selected bodies of water.

If benefits are to be derived at the *national* level, research must be sponsored explicitly for that purpose, or one must wait for the decentralized efforts of researchers to produce conceptual frameworks and empirical relationships which can be properly aggregated to the national level. The latter alternative must be viewed as a "long-shot", as the implicit decision context (national efficiency gains and losses) is not one which attracts decentralized research effort when the state-of-the-art is not well developed. The incentive system of most researchers stimulates performance of relatively "safe" projects, such as introducing methodological innovations in analysis of situation-site-specific cases.

Especially relevant for purposes of aggregation is the need for the analyst to consider the entire set of recreational options as perceived by the consumer, and then to analyze how water pollution at one or more sites affects consumption behavior at all sites. Analysis at present (even for small studies) is usually quite partial; no attempt at "netting out" is made. This approach, inherent in small-scale analysis, must be explicitly abandoned in any research attempts to move toward aggregate estimates.

Whether viewed from a perspective of assessing national or local water quality benefits, the principal limitation is the inadequate documentation of a variety of damage functions which relate changes in water quality parameters to changes in consumer behavior. Moreover, in most of the damage functions which have been documented, a key water quality parameter is assumed by the analyst, and its relationship to consumer behavior is derived (e.g., Stevens, 1966). Additional attention needs to be paid to perception of water quality by the recreationist, which may be considerably at odds with the scientist's perception.

Most studies consider only the recreational value of a body of water in its current state, where one or more water quality parameters are not up to standard, and its recreational value if the quality standards were to be met. Such two-point analyses must presume a linearity of value between points, which is probably not valid. For example, bringing the DO levels in a certain river up to 3 ppm might have positive net benefits, whereas at 5 ppm, the incremental costs might far outweigh the benefits. Unless a range of water quality levels is considered, the existing standard is assumed as a parameter, when in fact it might more usefully be considered as a variable.

One area of needed research is the estimation of the income elasticities associated with various water-based activities. Not all leisure or water-based activities have positive income elasticities. One might hypothesize that the income elasticity for swimming in rivers which run through major industrial centers is quite low, and perhaps even negative. In fact, it might further be hypothesized that what appears to be a substantial cost of pollution (i.e., the abandonment of swimming in industrial rivers) is a phenomenon which largely would have occurred in any event through income growth and the substitution of other leisure activities, particularly those which involve travel to less congested and more attractive sites.

If this hypothesis is valid, and it appears tractable to testing, then the implications are substantial. Rather than reclaiming these rivers on efficiency grounds, as assumed in national benefit-cost computations, the reclamation could be justified on distributional grounds (as compensation to those whose incomes do not allow them to recreate elsewhere), and/or to preserve the option to go back to older forms of recreation at some time in the future, is worth the cost, and/or on the basis of "national pride".

The benefits of pollution control can be regarded as the extra travel costs imposed on consumers by water quality constraints which are exogenous to their control. To infer that these benefits from pollution control are the same as what appear to be the damages of pollution may seem valid intuitively, but the symmetry between the two needs to be examined closely.

Unusual income elasticities may cause pollution control benefits to be less or more than the apparent damages of pollution. Recreational preferences are not acquired instantly, and hence are subject to private and public influences, some of which are both strong and pervasive. One such influence is the encouragement of travel through production of both super-highways and super-autos. Hence, there may be substantial lags in returning to urban water-based activities even if all bodies of water were brought back up to standard. Higher energy prices do, of course, pose a constraint to travel, as do the "psychic costs" of driving crowded freeways to escape the crowded city.

One can find micro cases in which the reduction in travel cost would lead to negative benefits. For example, consider two sites of unequal quality, the one farther away being the more desirable. Then if pollution destroys the (more valuable) distant site, the recreationist turns to the less desirable, closer site, and saves travel costs. While this does in fact happen (e.g., in over-use of some high mountain lakes), the model may be appropriate in a macro sense. That is, in terms of absolute magnitudes, water pollution has generally been urban-oriented and people have been forced to travel more, rather than less, to find comparable substitutes.

An ambivalence can be reached on incorporation of the costs of time in recreation benefits in that the opportunity cost of time spent in travel is more likely to be other leisure activities forgone than income generation. To value time at zero, however, might imply that alternative leisure activities are of zero utility; this is not a reasonable argument. It would seem that from an ex ante viewpoint, the expected gains from recreating would at least equal the expected costs, including opportunity costs of forgoing other recreational alternatives, some of which are substitutable with money and, hence, have a positive monetary value.

The net effect of all these considerations is not obvious, and hence, is deserving of research. The conclusion at this point is that the terms "pollution damages" and "pollution control benefits" should not be equated lightly.

A dynamic, simultaneous setting is the reality with which analysts must deal. In this setting, the economy and its system of distribution provides a driving force in re-shaping consumer preference, both through allowing greater discretionary income and in motivating consumers on how and where to spend it. Moreover, economic growth, in part through uncompensated negative externalities, imposes constraints on the range of goods and services which the recreationist can purchase (e.g., "no swimming" signs).

Two conceptual models, presented in Attachments A and B, may be useful in making aggregated assessments of recreation benefits from water pollution control. Model 1 demonstrates the conceptual links between quality, quantity, and price of the recreational experience. Model 2 demonstrates the usefulness of a "reduction in travel cost" construct and specifies data requirements for its implementation.

The typical recreationist finds that water pollution reduces the quality of his recreation experience, causes him to recreate less often, and causes him to incur higher travel costs to enjoy substitute sites. The objective of Model 1 is to demonstrate that these three components (quality, quantity, and price) are conceptually linked, and that addition of the three as separate components is not defensible.

Model 2 (Attachment B) moves toward establishing theory which may be useful in specifying data requirements for assessing national benefits. As a corollary, it may also be useful in interpreting whether or not existing empirical studies and data are of value in attempting to generate estimates of national benefits. The implications of Model 2 are that decreases in travel costs due to pollution abatement represent potential benefits from abatement, existing data on total costs of recreation should be explored as a proxy for travel cost data, and the empirical relationship between pollution levels and travel costs must be established before the model can be implemented empirically.

4. Aesthetic and Ecological Benefits

We have seen that the methodology for simulation of changes in market values for active recreational activities, as a function of changes in water quality, is still being developed and as yet, has not been adequately generalized to a national aggregate. The methodology for monetizing the less active (e.g., viewing) or more latent (e.g., future consumption) uses is even less developed. At present, there is little conceptual or empirical support for any available estimates of national aesthetic benefits from water pollution control.

A specific problem which links the categories of outdoor recreation and aesthetics is whether to believe what people say, or to believe, instead, what they do. Economists have long had a preference for the latter, fearing the lack of appropriate decision context in the former method. In short, people may overstate their willingness to pay if they think it will help secure a good, or they may understate their willingness to pay if they fear that their pocketbooks will somehow be affected. Although economists have long recognized these tendencies, there is relatively little in the literature in the way of constructive analysis on the avoidance of under or overstatement. The work by Bohm (1971) and Tideman (1972) are exceptions, but the reliance on assumption is still substantial there.

The constraint imposed by inadequate methodology is especially apparent when one considers the dilemma that exists where direct questioning appears to be the only available methodology. In the case of option demands on the part of the current non-users, the questioning must be with respect to desire for future consumption. Hence, there is no way to check results of direct questioning against observed behavior. In hypothetical cases of improved water quality, the general question is "What would your recreation preference set be if certain water quality parameters were varied?". In addition to problems that the recreationist might have in visualizing the improvement, there is again the absence of empirical cross-checks.

Despite this apparent dilemma, economists have had little propensity to seek help from other disciplines. Even in cases where the wording and setting of particular questions are crucial to the results, economists have usually preferred to "go it alone" rather than seek inputs from psychologists, social psychologists, or communication theorists. On the other hand, the non-economic literature on "environmental perception" is flourishing, but usually with no handles by which to impute monetary values.

Analysis of cross-section and time-series data is much preferred to direct questioning, if the data are available. Cross-sectional and time-series analysis can be designed to reveal consumer behavior in terms of what people actually do in response to changes in water quality. The basic problem is the lack of data with which meaningful analyses can be made.

Although the theoretical literature is far ahead of the empirical work, the theory itself is plagued with ambiguities which only time and intellectual effort can unravel. Its evolution dates back only a few years and the implication for pollution control benefits is that something in excess of consumers' surplus of current users is ususally appropriate and legitimate. The extent of this "something" is the crucial issue.

In spite of this evolutionary condition, several vital dimensions of the problem are now being addressed in the literature:

- The role of risk-preference versus risk-aversion
- Policy outcomes as public goods (and the concomitant implications for direct questioning)
- Uncertainty as to future supply and/or demand
- Relevance of contingent claims markets as analogs
- Mixed-good (private and social) conception of environmental goods.

Current empirical work is limited in its applicability for generalization, in that it focuses on high quality, unique environmental services, rather than medium or low quality services. This is not to dispute the future methodological value of such work, only to point out that the ratio of option value to (current) consumers' surplus may be quite different for Hells Canyon than for more mundane activities on the Delaware River.

One would hypothesize that the ratio of option value to consumers' surplus would be higher for the more unique sites, and that aggregation based on current empirical work would overstate total benefits. The rationale behind this hypothesis lies in the differential income elasticities for high and low-quality environment services. One would suspect the demand for high-quality services is more income-elastic than that for services of lower quality. Thus, the former will become relatively more valuable in the future, and consumers would be more likely to desire "insurance" of future supplies, should contingent claims markets exist. Individual investigators appear most likely to analyze unique, high-quality sites. In order to test the above hypothesis, one may need to promote similar research efforts for non-unique, lower-quality sites, rather than wait for decentralized researchers to ask this question.

Economists and administrators are in a rather obvious dilemma as to the extent to which option value estimates should be added to current user values. A market failure symptom is evident in the sense that contingent claims do not exist for environmental goods in the sense that they exist for some other goods. On the other hand, the current ability to estimate option values is admittedly weak, and may cast doubts on the validity of the more concrete estimates in other categories.

5. Property Values

The academician's traditional wisdom in benefit-cost analysis has been to exclude from consideration as efficiency benefits any increments in property values arising from public investment for which there is no corresponding increase in the output of goods or services. In other words, pecuniary externalities or simple income transfers have been netted out of the analysis. On the other hand, if there is in fact an increase in the output of goods or services, a more direct measure than property value increments is usually sought. For example, if crop damages were averted by flood control, both higher farm incomes and higher land values, due to higher farm incomes, would result. In this case, one would prefer to use the increase in net farm incomes as the measure of benefit.

Nevertheless, increments to property values do arise as a result of water quality improvement. This has been substantively documented by Dornbusch and Barrager (1973) and David and Lord (1969), although both the capability for generalization and the adequacy of their model specification must be questioned. David and Lord's measurement of water quality was much less precise than desired for purposes of extrapolation, and the Dornbusch and Barrager effort failed to measure water quality explicitly. These are inadequacies that can be rectified with further effort; the real question is the meaning, in the context of national efficiency, of even more adequately derived estimates. That is, what do increments in property values really reflect? The recent conclusion by Lind (1973) is that, in a general equilibrium model, most increments (or decreases) in land values can be ignored for benefit computation.

Property value increments may reflect an actualized option demand which should be included as an efficiency benefit. Pursuit of the relationships between water quality and property values should be viewed seriously from a strategic point of view, considering that existing behavioral damage functions for recreation and aesthetics are currently not capable of generalization to national levels.

The methodologies for estimating both recreation demands and option demands often rely on direct elicitation of responses, whereas property markets tend to reflect what people do, rather than what they say they will do. Since public access to water is increasingly difficult, property values may increasingly reflect an actualized option demand wherein buyers seek to assure, for private use, a continued supply of particular environmental services. To the extent that these option demands are satisfied, a service is produced by pollution control.

If sufficient relationships between water quality and property values were to become available, these might be used to derive generalized benefit estimates in terms of increments to property values. Caution would be needed to avoid "double-counting". On the other hand, those to whom property value increments would accrue are probably a small fraction of total active users.

More refined lines of questioning could be developed to explore option demand, including the degree to which people seek to secure greater certainty over resource services through property acquisition. To the extent that property acquisition does act as a hedge against uncertain future supplies, there is a "corresponding increase in the output of goods or services," and the criteria for benefit computation are not violated.

E. CONCLUSIONS AND RECOMMENDATIONS

This section lists the conclusions drawn from the foregone discussion and recommendations for future work.

The analytical base of welfare economics and U.S. EPA's data collection capability both provide hope for better benefit estimates. Although numerous other problems exist, the analytical foundations of welfare economics and the data collection capability of U.S. EPA both provide a basis on which to expect that improved benefit estimates can be obtained. As Tihansky (1975) points out in his detailed literature review, welfare economics provides a significant conceptual base which has not been rigorously adhered to in much of the empirical work. The theory for estimation of benefits is far more advanced than the empirical work; hence, welfare economics, *per se*, is not a limiting factor.

The estimates of national benefits, by category of benefit, now have vastly different precisions. Until these categories are made more nearly comparable, there is little capability for judging to what degree investment in water pollution control would be efficient. Estimates of *production* losses, including traditional waterborne disease, are reasonably firm, although they could be improved at a cost. However, estimates of *consumption* losses, including recreation, aesthetics, and survival dimensions of health, are much less firm.

The general prospects for improving the precision of estimates also differ greatly over the various categories. Additional analytical effort along conventional lines can resolve much of the variation in the production estimates. Also, technological change (biased toward production rather than consumption activities) may retard the rate at which these benefit streams grow over time. Increased precision in estimates of recreation benefits and option values will come slowly and probably fortuitously in the absence of a coordinated effort in benefit estimation.

Highest priority should be directed to generation of behavioral response functions which are more complete and useful than those few *which now exist*. Principal attention should be directed to generation of meaningful behavioral response functions with respect to water quality changes, which improves their capability for aggregation and provides a more general framework. It seems almost a hopeless strategy for U.S. EPA to continue retaining even the best consulting firms to periodically make efforts toward extrapolating existing studies, when the base studies themselves are not designed to be extrapolated.

Criteria need to be established to identify and fund high priority research on behavioral response functions. The ambitous nature of the current decision context, that of weighing aggregate national benefits against aggregate national costs, must be reconsidered; suboptimization in research design should become a pragmatic reality. Decision criteria then need to be set to identify and fund high-priority research settings in which to generate behavioral response functions to changes in water quality. A matrix relating types of pollutants to geographic regions should be identified, and priorities for future research established. The criteria which would be needed to set priorities, among different elements of the matrix, should include consideration of the current level of pollution control benefits, considering both mean values and differential precision of the estimates, the rate at which the benefit streams appears to be growing or declining, the likely cost (in money and time lag) of establishing the behavioral relationships.

The set of behavioral response functions should include services for which "option demands" might be exercised. Within the set of behavioral relationships to be identified are those which relate to willingness to pay to increase the certainty of future provision of selected consumption goods and services. The latter may include access to or availability of recreation activities or aesthetic uses where water quality is a consideration and avoidance of waterborne health hazards (e.g., carcinogens and toxic chemicals).

A "reduction in travel cost" model offers potential for assessing recreation benefits at a level of aggregation higher than that which now exists. Empirical implementation of such a model will be more difficult than specification of theory. Crucial elements include identification of the entire set of water-based recreation activities within the preference set of the consumer and specification of subjective substitutability or complementarity between sites. Also, measurement of how water quality differences are related to these elements, ability to measure this relationship on a continuum, rather than for "clean" water and "polluted" water, and ability to test the equality of degradation versus restoration of water quality.

A basic commitment should be made by EPA to establish a long-term "behavioral monitoring system" analogous to that established by the U.S. Geological Survey for assessing water quality. The data sets for a carefully selected variety of sites would include measurement of basic economic and ecological data, objective and perceived water quality parameters, recreation activity, by type, intensity, and other characteristics, and property values, particularly for residential and recreational properties. The monitoring system would be longitudinal in that trends in both water quality and user behavior would be recorded, allowing for time-series analysis.

Selection of a variety of sites would also allow cross-sectional analysis. Periodic cross-sectional sampling could be done among recreationists and potential users. This sampling would not need to be done necessarily on a large-scale basis, but it would need to be done well. Samples of users could also be followed longitudinally; a substantial literature now exists on this methodology. Criteria would need to be established for selection of sites. Consideration should be given to selection of sites where significant changes (upward and downward) are occurring or are likely to occur in the water quality parameters and to selection of sites which differ significantly in socio-economic variables (so as to allow cross-sectional estimates of income elasticities).

The rationale behind the proposal to establish a monitoring system are:

- More adequate knowledge of behavioral responses with respect to price, income, and (perceived or objective) water quality changes need to be established before national benefits can be estimated

- Current inferential capacity of analyses based on direct questioning is largely unknown
- Changes in water quality are in fact occurring, and researchers should be taking advantage of this
- The conceptual and empirical dimensions of "option demand" are still evolving; the theoretical models ten years hence may well be more powerful than can be tested against the data unless steps are taken to accumulate a large set of data
- A monitoring system provides a continuing flow of information to decision makers and to their constituency; over time, behavioral relationships can be determined and made available, thus augmenting this flow of information as well as facilitating much more precise estimates of national benefits from pollution control.

REFERENCES

Barker, Bruce, and Paul Kramer, "Water Quality Conditions in Illinois," in Statewide Water Resource Development Plan 1972, Illinois Department of Transportation, Division of Water Resource Management, 1973.

Bohm, Peter, "An Approach to the Problem of Estimating Demand for Public Goods," Swedish Journal of Economics 73(1):94-105, March 1971.

David, Elizabeth L., and William B. Lord, Determinants of Property Value on Artificial Lakes, University of Wisconsin, Department of Agricultural Economics, May 1969.

Dornbusch, David M., and Stephen M. Barrager, Benefit of Water Pollution Control on Property Values, U.S. Environmental Protection Agency, EPA-600/5-73-005, October 1973.

Freeman, A. Myrick III, "A Survey of the Techniques for Measuring the Benefits of Water Quality Improvement," in Peskin, Henry M., and Eugene P. Seskin (eds.), Cost Benefit Analysis and Water Pollution Policy, The Urban Institute, Washington, D.C., 1975.

Haveman, Robert H., and John V. Krutilla, Unemployment, Idle Capacity, and the Evaluation of Public Expenditures, Johns Hopkins Press, Baltimore, 1968.

Haveman, Robert H., and Burton A. Weisbrod, "The Concept of Benefits in Cost-Benefit Analysis: With Emphasis on Water Pollution Control Activities," in Peskin, Henry M., and Eugene P. Seskin (eds.), Cost Benefit Analysis and Water Pollution Policy, The Urban Institute, Washington, D.C., 1975.

Krutilla, John V., "Conservation Reconsidered," American Economic Review 57(4): 777-786, September 1967.

Lackner, Jack, Safe Drinking Water Act of 1973: Estimated Benefits and Costs, U.S. Environmental Protection Agency, 1973.

Lind, Robert C., "Spatial Equilibrium, The Theory of Rents, and the Measurement of Benefits from Public Programs," Quarterly Journal of Economics 87(2):188-207, May 1973.

Lindblom, Charles E., "The Science of Muddling Through," Public Administrative Review, pp. 79-88, Spring 1959.

Liu, Oscar C., Illnesses Associated With Human Enteric Viruses, U.S. Environmental Protection Agency, Northeast Water Supply Research Laboratory, 1970.

Meyer, Philip A., Recreational and Preservation Values Associated With the Salmon of the Fraser River, Fisheries and Marine Service, Vancouver, B.C., Canada, Information Report Series, No. PAC/N-74-1, 1974.

Peskin, Henry M., and Eugene P. Seskin (eds.), Cost Benefit Analysis and Water Pollution Policy, The Urban Institute, Washington, D.C., 1975.

Schultz, T. W., "Institutions and the Rising Economic Value of Man," American Journal of Agricultural Economics 50:1113-1122, December 1968.

Sokoloski, A., Economic Benefits of an Adequate Supply of Safe Water, U.S. Environmental Protection Agency, 1973.

Stevens, Joe B., "Recreation Benefits from Water Pollution Control," Water Resources Research 2(2):167-182, 1966.

Tideman, T. Nicolaus, "The Efficient Provision of Public Goods," in Selman J. Mushkin (ed.) Public Prices for Public Products, The Urban Institute, Washington, D.C, 1972.

Tihansky, Dennis P., "An Economic Assessment of Marine Water Pollution Damages," Proceedings of the Third International Conference on Pollution Control in the Marine Industries, June 5-7, 1973.

Tihansky, Dennis P., "A Survey of Empirical Benefit Studies," in Peskin, Henry M., and Eugene P. Seskin (eds.), Cost Benefit Analysis and Water Pollution Policy, The Urban Institute, Washington, D.C., 1975.

Unger, Samuel G., et al., National Estimates of Water Quality Benefits, Development Planning & Research Associates, Inc., November 1974.

U.S. Department of the Interior, Westwide Study Report on the Critical Water Problems Facing the Eleven Western States, 1974.

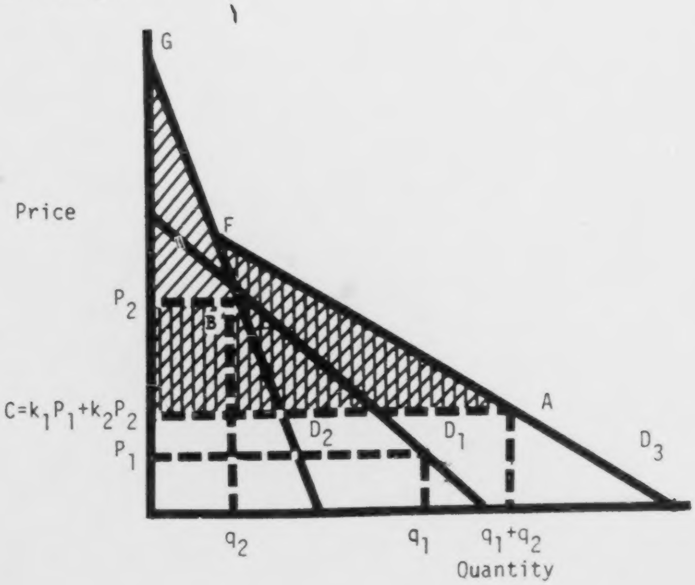
ATTACHMENT A. MODEL 1

Assume that a recreationist has separate demand functions (D_1 and D_2) for two non-priced sites which have, in his subjective judgment, some degree of substitutability. Assume also that these two sites constitute his "demand for outdoor recreation" (D_3). The demand function for each site is a function of both price (travel cost) variables and the quality parameter (Qu) of the site itself. Hence:

$$Q_1{}^d = f(P_1, Qu_1, P_2)$$

$$Q_2{}^d = f(P_2, Qu_2, P_1)$$

Diagrammatically:



Assume further that the relative price structures are such that the price of Site 1 (P_1) is low relative to the price of Site 2 (P_2), so that the quantity, q_1, exceeds q_2. Viewing the aggregate demand function, D_3, the implicit "before pollution" price is $k_1p_1 + k_2p_2$, where the k_i's are weights determined by optimum quantities, q_1 and q_2. The total consumer's surplus which he derives is equal to CAFG.

Now assume that water quality at Site 1 deteriorates to the point that the recreationist no longer has any effective demand for this site. Such an event obviously reduces the utility of the consumer. When Site 1 disappears from the consumer's utility function, his equilibrium position changes from point A to point B. There is a reduction in his total quantity taken, an increase in the unit price paid (though not in the total bill), and a decrease in his utility. His consumer's surplus is now P_2BFG, and the double cross-hatched area (CAFBP_2) is his reduction in consumer's surplus due to pollution.

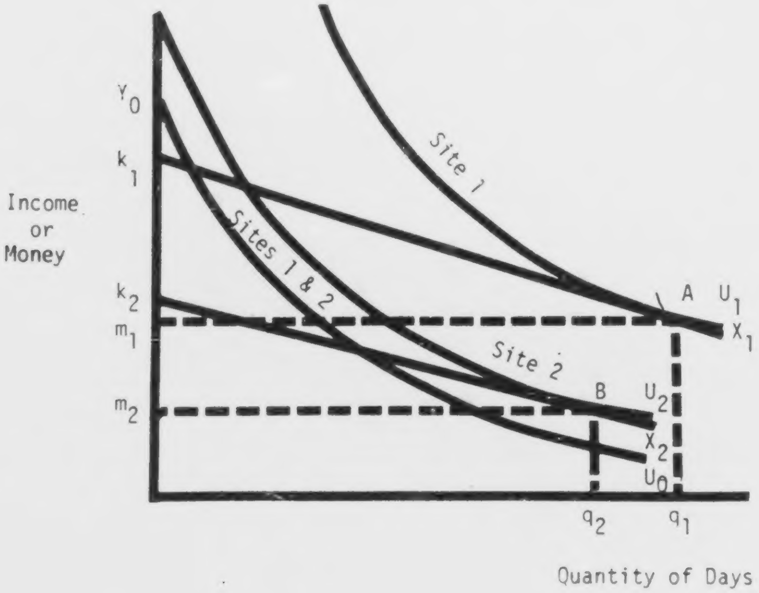
If the loss of Site 1 to pollution causes his demand for Site 2 to shift outward and become more inelastic (fewer substitutes), as might be expected, then the above decrease in willingness to pay has been overstated. Conversely, if the pollution of his "favorite" stream causes him to quit fishing, for example, altogether (due to inter-relatedness of sites and complementarity in terms of fixed factors such as tackle, etc.), then the reduction in willingness to pay is equal to CAFG, less the salvage value of his equipment.

ATTACHMENT B. MODEL 2

Consider that in a "no-pollution" situation, a recreationists's utility mapping for Site 1 or 2 contains indifference curve U_0 which passes through his current income position, Y_0. His willingness to substitute income to obtain additional units of recreation along U_0 is identical between Sites 1 and 2. That is, the two sites are perfect substitutes for each other.

The cost of travel to the two sites, however, differs; Site 1 can be reached for a fixed outlay of (Y_0-k_1), which is essentially the cost of travel, lodging, and/or food required to reach and return from the site. Once the fixed costs of reaching the site are incurred, the variable costs (k_1X_1) per unit of time (e.g., on-site lodging and/or admission fees) become relevant in determining his optimum length of stay.

Site 2 is located farther from his home, thus the fixed costs of travel (Y_0-k_2) exceed those for Site 1. Assume, for simplicity, that the variable or on-site costs of the two sites are equal, or that (k_2X_2) is parallel to (k_1X_1).



In that the two sites are defined (initially) as perfect substitutes and their relative prices are unequal, a corner solution is reached. The recreationist will reach a higher (than U_0) indifference curve if he sacrifices (Y_0-m_1) income and consumes q_1 days at Site 1 (i.e., point A on indifference curve U_1).

Assume now that water quality at Site 1 deteriorates to the point where he is no longer willing to sacrifice income to enjoy Site 1. Under the assumption that the demand for each site is a function of both site prices and its own quality dimension (i.e., U_2 retains the same curvature as U_0 and U_1, but is now relevant only for Site 2), the recreationist will now turn to Site 2, which can be reached only at higher travel costs. His optimum level of consumption is now q_2 days (all taken at Site 2) with a money outlay of (Y_0-m_2); i.e., point B on indifference curve U_2.

Note at this point that the model is probably of general relevance in that:

- Pollution leaves the consumer "worse-off" than before
- Pollution causes the distance traveled to increase
- Some recreation is still consumed, even though a site is "lost" to pollution
- The total money outlay for recreation increases as pollution and per-unit prices increase (i.e., the demand for outdoor recreation, in general, would seem to be inelastic, as with most broad categories of commodities)
- Variable or on-site costs probably do not differ greatly between non-polluted and previously non-polluted areas.

The model is simplistic, however, in that the two sites are initially defined as perfect substitutes, differ only in distance, and constitute his entire recreational demand. (The limiting nature of his assumption has important implications, to be discussed below.)

The "costs" of pollution, to the recreationist, can be defined as the reduction in willingness to pay which is incurred through pollution.

Similarly, the benefits to restoration of clean water (or prevention of damage) can be seen as the same quantity. Each is a mirror image of the other, ceteris paribus.[1] The Hicksian concept of "compensating variation" allows us to approximate the monetary value of this averted utility loss or potential utility gain. It asks: "How much would the consumer[2] have to be compensated to leave him as well off as before?" In this model, utility level U_1 could be regained by an outward shift in the price line from (k_2X_2) to (k_1X_1); i.e., an income transfer of the magnitude (k_1-k_2), or the difference in the fixed costs of travel, could leave the recreationist as well off as he was prior to pollution, given that on-site costs are the same in both cases.

This model illustrates two things. First, if the recreation sites are initially perfect substitutes, the relevant measurement of benefit is isolated in terms of additional travel costs alone. Any measures of benefits from quantity and quality changes are clearly duplicative, since they are already incorporated in the reasoning and diagram above. The model says this; if pollution causes a recreationist to incur $10 in additional travel cost to reach a more distant site, a $10 income transfer to him would theoretically leave him as well off as before, and hence, is a measurement of values foregone by pollution -- or benefits created by restoration. Second, the model identifies crucial needs for (a) extent to which pollution has caused substitutions between sites, and (b) data on additional per unit travel costs due to pollution. While these may or may not be available, the differences in total outlays (m_1-m_2) might be a suitable proxy.[3]

---

[1] The critical limiting nature of this ceteris paribus assumption is examined on pages IV 21-22.

[2] The analysis is shown for those who participate in at least some recreation both with and without pollution. Other recreationists, however, would cease this type of consumption altogether with the demise of Site 1 (i.e., move to Y_0). In any empirical treatment, the willingness to pay of these (marginal) consumers would need to be added to that of existing (intramarginal) consumers.

[3] I would note, however, a difference in the ratios $\left(\frac{Y_0-m_1}{Y_0-m_2}\right)$, and $\left(\frac{Y_0-k_1}{Y_0-k_2}\right)$. If, for example, moving from B to A represents a 40 percent reduction in total costs $\left(\frac{Y_0-m_1}{Y_0-m_2} = 0.6\right)$, then this might involve (say) a 60 percent reduction in travel costs $\left(\frac{Y_0-k_1}{Y_0-k_2} = 0.4\right)$.

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/5-78-014	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE CRITICAL REVIEW OF ESTIMATING BENEFITS OF AIR AND WATER POLLUTION CONTROL		5. REPORT DATE 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) A. Hershaft (ed.); A. M. Freeman III; T. D. Crocker, J. B. Stevens		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Environ Control, Inc. 11300 Rockville Pike Rockville, Maryland 20852		10. PROGRAM ELEMENT NO. 1HA094 11. CONTRACT/GRANT NO. Contract No. 68-01-2821
12. SPONSORING AGENCY NAME AND ADDRESS Office of Research and Development U. S. Environmental Protection Agency Washington, D. C. 20460		13. TYPE OF REPORT AND PERIOD COVERED Final 14. SPONSORING AGENCY CODE EPA-ORD

15. SUPPLEMENTARY NOTES

Project Officer - Thomas E. Waddell

16. ABSTRACT

This report provides a critical review of the current state-of-the-art and future prospects of estimating benefits of air and water pollution control. This report represents three independent critiques by three experts of benefit assessment methodologies. Specific aspects discussed include the nature and role of benefits, damage functions, valuation of effects, aggregation of results, and representation of uncertainties. The conceptual foundations of estimating pollution control benefits were presented and compared with empirical studies. It was concluded that while available estimates often do not adequately reflect the state-of-the-art, estimates of pollution control benefits would potentially be very useful to decision makers. The conceptual basis provided by economic theory for benefit estimation is adequate in most respects and far ahead of the corresponding empirical effort. A number of studies are guilty of failing to list explicitly critical assumptions or to express adequately uncertainty in the results while other studies have employed conceptual models that are inappropriate to the problem at hand or the available data. Damage functions underlying benefit estimates are frequently based on insufficient data and/or inadequate characterization of exposure and effects. National benefit estimates were found to be based on regional studies which are frequently inadequate in number and/or quality.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Economic Analysis Economic Surveys Air Pollution Water Pollution	Environmental Economics Environmental Impacts Benefit/Cost Analysis Economic Efficiency Pollution Abatement Benefits Pollution Effects	5C 20A

18. DISTRIBUTION STATEMENT Distribution Unlimited - Available through: National Technical Information Service Springfield, Va. 22151	19. SECURITY CLASS *(This Report)* UNCLASSIFIED 20. SECURITY CLASS *(This page)* UNCLASSIFIED	21. NO. OF PAGES 22. PRICE

EPA Form 2220-1 (9-73)

THE BENEFITS OF AIR AND WATER POLLUTION CONTROL:
A REVIEW AND SYNTHESIS OF RECENT ESTIMATES

by

A. Myrick Freeman III*
Bowdoin College
Brunswick, Maine 04011

A report prepared for
the Council on Environmental Quality

December, 1979

*I would like to acknowledge the helpful comments and suggestions of Alan Carlin, Thomas Crocker, Donald Gillette, John Jaksch, Kay Jones, Lester Lave, Ben-Chieh Liu, Jon Nelson, Paul Portney, Clifford Russell, Eugene Seskin, William Schulze, Richard Schwing, William Watson and Ronald Wyzga. Of course I bear sole responsibility for any errors, and for all judgments, interpretations, and conclusions.

EXECUTIVE SUMMARY

Introduction

Perhaps the most important economic aspect of environmental regulation is the relationship between the benefits and the costs of regulatory policies. It is the purpose of this study undertaken for the Council on Environmental Quality to shed some light on the benefits associated with federal air and water pollution control programs. This is not to be done through the collection of new data or the estimation of a further set of statistical relationships between environmental improvements and physical or economic well-being. Rather, this report is an attempt to review and synthesize the large number of previous studies of the benefits from air and water pollution control.

The report has four major objectives. The first is to provide a critical review of those previous studies which have attempted to estimate air and water pollution control benefits in monetary terms or which might provide an empirical basis for making such an estimate. This review evaluates the theoretical framework underlying each of the estimates, the validity of the estimation technique, and the adequacy of the data.

The second objective of this report is to explain why previous studies have come up with such different estimates of the benefits arising from air and water pollution control policies. Briefly, there are four reasons. First, the various studies have not expressed the monetary benefits in dollars reflecting the same price level. Next, these same studies have used different base periods for environmental and socioeconomic conditions; more importantly, they have based the benefit calculations on very different assumptions about environmental improvements.

Third, the previous studies have resulted in conflicting estimates of the physical effects of pollution, for example, dose-response relationships linking air pollution and human health. Finally, previous studies have assigned quite different monetary values to improvements in human health or other favorable effects of environmental policy.

In view of these differences, the third objective of this study is to recalculate benefit estimates whenever possible on the basis of a common set of assumptions concerning price level, base period, degree of cleanup, and imputed values so as to compare the different estimates of air and water pollution control benefits. Such a standardization isolates differences in the underlying physical relationships identified in the studies.

The fourth objective is to synthesize the results of the various studies reviewed and present "best judgment" estimates of benefits based on available evidence.

The first three objectives involving the review and comparison of previous studies are quite technical and comprise the bulk of this report. These results are difficult to summarize, and little more will be said here about the details of the individual studies surveyed and their strengths and weaknesses. The rest of this summary is devoted to the synthesis or best-judgment estimates, including a discussion of how they were derived.

First, the study presents upper and lower bounds for the estimates of air and water pollution control benefits. This range reflects the uncertainty and possible error in the estimates of various categories of benefits in the studies. The range of uncertainty in some cases is quite substantial -- high and low estimates of benefits frequently differ by a factor of ten. No formal probability framework was employed in establishing these upper and lower bounds. Rather, they reflect the author's expert judgment that there is a roughly ninety percent chance the true value lies within the range.

The study also presents what are called "most reasonable point estimates" for the various categories of benefits. These are averages of existing estimates weighted by the author's judgment concerning the validity and reliability of the various estimates. Where two or more studies appear to be equally reliable, most reasonable point estimates were derived by averaging the values of the various studies. However, where one benefit study seems to be superior to others in terms of quality of the evidence, it was given greater weight in the derivation of the most reasonable point estimate.

The reader should be careful not to use the most reasonable point estimates without also citing the upper and lower bounds. If stated alone, the most reasonable point estimates might convey a false sense of accuracy or certainty about inherently inaccurate and uncertain values.

Air Pollution

The estimates of the benefits of air pollution control are based on 1978 population and economic conditions. On the basis of EPA data on air quality trends, this study assumed an average improvement of 20 percent in air quality as measured by ambient concentrations of total suspended particulates and sulfur oxides. CEQ analysis of data on the number of days on which national photochemical oxidant standards were violated provided the basis for some assumed improvements in oxidant levels for the nation.

The study examined estimates of air pollution control benefits in the categories of improvements to human health, reduced soiling and cleaning costs for households, reduced damages to vegetation and crops, and reduced damages to materials. It also reviewed estimates of air pollution control benefits derived from studies of property value differences. Property value measures will tend to capture benefits in some or all of the above four categories. Thus to add them to the other measures would likely involve double counting. However, the property value measures may also capture aesthetic values which are not included in any of the above categories. On the basis of a survey of households in Los Angeles conducted by David Brookshire and others at the University of Wyoming, it was estimated that 30 percent of property value benefits were the result of improvements in aesthetic values and should be added to the benefit estimates in the other categories.

On the basis of these assumptions, this report concludes that the total national benefits which have been realized from reductions in air pollution since 1970 lie in the range from roughly $5 billion to $51 billion per year. The most reasonable estimate of the annual benefits of air quality improvements being enjoyed in 1978 is $21.4 billion.

Several points should be made about these estimates. First, they represent only to the benefits associated with realized improvements in air quality since 1970. If, as many believe, the Clean Air Act has not only resulted in improved air quality over 1970 levels, but has also helped prevent further degradation, "true" benefits are larger than the totals presented in this report. Therefore, to the extent that the range and most reasonable point estimate of air pollution control benefits ignore degradation prevented, they should be viewed as quite conservative.

Next, no previous studies have attempted to assess the benefits in other countries resulting from air pollution control in the United States. Because of trans-boundary air pollution, it is likely that both Canada and Mexico have enjoyed benefits in one or more of the categories identified above. Yet these are not included in this report.

In addition, while this report discusses several estimates of the benefits of increased visibility, these were not sufficient to form the basis for an estimate of the national benefits of improved visibility. Hence, these are omitted from the totals presented in the report.

Finally, the estimates are based on an assumed uniform improvement in air quality across the nation. In actuality some areas have enjoyed substantial improvements in air quality while other areas have experienced stable or in some cases deteriorating air quality. A more accurate estimate of national benefits would be one based on separate estimates of the benefits in each region associated with actual air quality experience there and conditioned upon each region's specific socioeconomic conditions. These regional totals would then be added to obtain a national aggregate benefit estimate. For some categories of benefits, the data necessary for this type of calculation are available. However the time and resources available to this study did not permit using this more detailed approach.

The benefits of reduced mortality resulting from reduced concentrations of suspended particulates and sulfur compounds account for 65 percent of the most reasonable point estimate of air pollution control benefits. The inclusion of morbidity reductions due to pollution control brings total health benefits to 80 percent of total air pollution control benefits.

Because the mortality benefits are such an important component of the total and because their estimation provides a good example of the difficulties encountered throughout this study, it is useful to describe in a little more detail how they were derived.

The estimate of mortality benefits is based on two key assumptions. The first is the change in mortality associated with the given change in pollution levels. The second is the monetary value to be attached to reductions in mortality. It proved most convenient to state the relationship between air pollution and mortality in the form of an elasticity (or percentage change in mortality for a given percentage change in air pollution) computed at the average values for the two variables. This report to CEQ examined studies of the air pollution-mortality relationship by ten different sets of authors. Many of them reported elasticities or the elasticities could be computed from their reported data. Most fell in the range of .01 to .1. This range was taken to be the lower and upper estimates of the effect of air pollution on mortality and the study took .05 to be the most reasonable point estimate.

However, it should be noted that there is a good deal of controversy surrounding these studies. The major issues concern the validity of air quality data from one or a few monitoring sites in each urban area as measures of the current exposures of the individuals residing in that area; the validity of current exposures as a measure of the long term exposure history relevant to explaining chronic effects and mortality; and the adequacy of control for such factors as age, socioeconomic conditions, smoking, diet, and exposure to other environmental health hazards. More research is being done on the connection between air pollution and health and it is to be hoped that the degree of uncertainty surrounding this critical relationship will be reduced.

The monetary value of reduced risk of mortality was based on individuals' apparent willingness to pay to reduce risk rather than on an opportunity cost or foregone earnings approach. After reviewing estimations of risk valuation by

Acton, Blomquist, Jones-Lee, Smith, Thaler and Rosen, and Viscusi, $1 million (in 1978 dollars) was used as the value of a statistical life. Readers of the report are free to choose other values for reduced mortality and to compute benefits accordingly. And those unwilling to engage in the exercise of imputing monetary values to reductions in mortality rates for populations at risk can still utilize the estimates of the reduction in mortality derived in the report. Based on results from previous studies, this report finds that between 2780 and 27,800 lives are saved per year as a result of air pollution control. The most likely number is 13,900.

Presented in Table 1 is a summary of the ranges and most reasonable point estimates for the various categories of air pollution control benefits analyzed in previous studies.

Water Pollution

For several reasons, water pollution control benefits are much more difficult to estimate than those arising from air pollution control.

First, there are many more indicators of water quality. Even in a particular water body, these indicators may take on very different values depending on the time and location of sampling. Since there is such a large number of water bodies and stream segments in the country, it is very difficult to make summary statements about water quality levels for the nation as a whole and how they have changed as water pollution has been reduced. Thus it is not possible to characterize in a very simple way the aggregate change in water quality resulting from federal law.

Second, the principal legislative tool for reducing discharges in the federal law is the effluent limitations required of point sources of pollution. Almost all previous studies of water pollution control benefits have focused on the beneficial effects of controlling discharges of the so-called conventional pollutants from point sources -- e.g., municipal waste treatment plants or industrial facilities. But in many water bodies non-point sources such as urban or agricultural run-off are significant contributors to degraded water quality. Estimation of the benefits of controlling non-point sources is made difficult both because of the lack of information on the effects of non-point source pollution on water users, and because of the difficulty in predicing the degree of control which is likely to be imposed on non-point sources. Therefore, any benefits that may result from the control of non-point sources, for example under §208 of the Federal Water Pollution Control Act (The Clean Water Act), are not included in previous estimates or in the synthesis estimates presented in this report.

There is an additional and important difference between the air and water benefit studies. The latter almost all estimate the annual benefits to be enjoyed beginning in 1985 when both stages of the Clean Water Act (the so-called BPT and BAT requirements) are to have been completed. However, since these previous studies do not estimate the benefits associated with each of these two stages, they do not permit a calculation of the benefits to be realized in 1978 or any other intervening year. Rather, the water pollution control benefits identified in this report are those to be enjoyed beginning in 1985.

The synthesis of previous studies presented in Table 2 below yields an estimate of the lower and upper bounds of water pollution control benefits of about $6.5 billion to almost $25 billion per year. The most reasonable point estimate of the benefits to be enjoyed by 1985 is $12.3 billion per year.

Over half of this total is attributable to improved water-based recreation. Another significant category is non-user benefits. These include enhanced esthetic appeal, option demand, improvements in residential property values near water bodies and reduced damage to ecological systems from conventional pollutants.

There is a very important respect in which the snythesis estimates presented in this report might understate considerably the true water pollution control benefits to be enjoyed in 1985. As indicated above, prior studies have dealt exclusively with removal of the conventional pollutants like fecal coliform bacteria, biochemical oxygen demand, etc. Yet the 1977 Amendments to the Clean Water Act redirected attention to the control of 65 toxic pollutant categories originating in 27 industries. The damage these pollutants cause to shell fish beds, commercial fisheries, and other aquatic ecosystems -- and hence the benefits arising from their removal -- was not included in earlier studies, and hence is not reflected in the totals in this report. Nor do the estimates presented here take account of the possible effects on human health of organic chemical or heavy metal contamination of drinking water. In fact, several studies cited in this report identified such a link. Nevertheless, they did not provide a sufficient basis on which to derive quantitative estimates of potential health benefits due to the removal of these contaminants. The exclusion of these two potentially very important categories of benefits must be considered in interpreting this report.

* * *

This report makes two points quite clear. First, in spite of recent advances, the estimation of certain kinds of environmental benefits is still in need of much additional refinement. The development and acquisition of data in a number of important areas will be one key to this refinement. Second, where state-of-the art analyses of environmental benefits have been undertaken -- as exemplified by the studies reviewed in this report -- they strongly suggest that environmental protection is good economics.

TABLE 1

Air Pollution Control Benefits Being Enjoyed in 1978
(In Billions of 1978 Dollars)

	Category	Realized Benefits Range	Realized Benefits Most Reasonable Point Estimate
1.	Health		
	A. Stationary Source Mortality	$2.8 - 27.8	$13.9
	Morbidity	$ .29- 11.5	2.9
	Total	$3.1 - 39.3	$16.8
	B. Mobile Source	$ 0 - .4	.2
	Total Health	$3.1 - 39.7	$17.0
2.	Soiling and Cleaning	$ .5 - 5.0	$ 2.0
3.	Vegetation		
	A. Stationary Source	0	0
	B. Mobile Source	$ .2 - 2.4	$ .7
	Total Vegetation	$ .2 - 2.4	$ .7

TABLE 1 (cont'd.)

4. Materials		
A. Stationary Source	$ .4-1.1	$.7
B. Mobile Source	.1- .3	.2
Total	$ .5-1.4	$.9
5. Property Values		
A. Stationary Source	$ .9-6.9	$ 2.3
B. Mobile	$ .2-2.0	$ .4
Total	$1.1-8.9	$ 2.7
GRAND TOTAL[a]	$4.6-51.2	$21.4

Notes

[a] Because of overlap, only 30 percent of property value benefits are added to other categories (see pp. 119-22).

Table 2

Benefits in 1985 from Removal of Conventional Water Pollutants

(in billions of 1978 dollars)

	Range	Most Likely Point Estimate
Recreation	$4.1-$14.1	$6.7
Non-User Benefits:		
aesthetics, ecology, property values	1.0- 5.0	2.0
Diversion Uses		
Drinking Water-Health	0.0- 2.0	1.0
Municipal Treatment	0.6- 1.2	0.9
Households	0.1- 0.5	0.3
Industrial Supplies	0.4- 0.8	0.6
Commercial Fisheries	0.4- 1.2	0.8
Total	$6.6-$24.8	$12.3

Federal Regulation

Executive Order 12291. February 17, 1981

By the authority vested in me as President by the Constitution and laws of the United States of America, and in order to reduce the burdens of existing and future regulations, increase agency accountability for regulatory actions, provide for presidential oversight of the regulatory process, minimize duplication and conflict of regulations, and insure well-reasoned regulations, it is hereby ordered as follows:

SECTION 1. *Definitions*. For the purposes of this Order:

(a) "Regulation" or "rule" means an agency statement of general applicability and future effect designed to implement, interpret, or prescribe law or policy or describing the procedure or practice requirements of an agency, but does not include:

(1) Administrative actions governed by the provisions of Sections 556 and 557 of Title 5 of the United States Code;

(2) Regulations issued with respect to a military or foreign affairs function of the United States; or

(3) Regulations related to agency organization, management, or personnel.

(b) "Major rule" means any regulation that is likely to result in:

(1) An annual effect on the economy of $100 million or more;

(2) A major increase in costs or prices for consumers, individual industries, Federal, State, or local government agencies, or geographic regions; or

(3) Significant adverse effects on competition, employment, investment, productivity, innovation, or on the ability of United States-based enterprises to compete with foreign-based enterprises in domestic or export markets.

(c) "Director" means the Director of the Office of Management and Budget.

(d) "Agency" means any authority of the United States that is an "agency" under 44 U.S.C. 3502(1), excluding those agencies specified in 44 U.S.C. 3502(10).

(e) "Task Force" means the Presidential Task Force on Regulatory Relief.

SEC. 2. *General Requirements*. In promulgating new regulations, reviewing existing regulations, and developing legislative proposals concerning regulation, all agencies, to the extent permitted by law, shall adhere to the following requirements:

(a) Administrative decisions shall be based on adequate information concerning the need for and consequences of proposed government action;

(b) Regulatory action shall not be undertaken unless the potential benefits to society from the regulation outweigh the potential costs to society;

(c) Regulatory objectives shall be chosen to maximize the net benefits to society;

(d) Among alternative approaches to any given regulatory objective, the alternative involving the least net cost to society shall be chosen; and

(e) Agencies shall set regulatory priorities with the aim of maximizing the aggregate net benefits to society, taking into account the condition of the particular industries affected by regulations, the condition of the national economy, and other regulatory actions contemplated for the future.

SEC. 3. *Regulatory Impact Analysis and Review*.

(a) In order to implement Section 2 of this Order, each agency shall, in connection with every major rule, prepare, and to the extent permitted by law consider, a Regulatory Impact Analysis. Such Analyses may be combined with any Regulatory Flexibility Analyses performed under 5 U.S.C. 603 and 604.

(b) Each agency shall initially determine whether a rule it intends to propose or to issue is a major rule, *provided that*, the Director, subject to the direction of the Task Force, shall have authority, in accordance with Sections 1(b) and 2 of this Order, to prescribe criteria for making such determinations, to order a rule to be treated as a major rule, and to require any set of related rules to be considered together as a major rule.

(c) Except as provided in Section 8 of this Order, agencies shall prepare Regulatory Impact Analyses of major rules and transmit them, along with all notices of proposed rulemaking and all final rules, to the Director as follows:

(1) If no notice of proposed rulemaking is to be published for a proposed major rule that is not an emergency rule, the agency shall prepare only a final Regulatory Impact Analysis, which shall be transmitted, along with the proposed rule, to

the Director at least 60 days prior to the publication of the major rule as a final rule;

(2) With respect to all other major rules, the agency shall prepare a preliminary Regulatory Impact Analysis, which shall be transmitted, along with a notice of proposed rulemaking, to the Director at least 60 days prior to the publication of a notice of proposed rulemaking, and a final Regulatory Impact Analysis, which shall be transmitted along with the final rule at least 30 days prior to the publication of the major rule as a final rule;

(3) For all rules other than major rules, agencies shall submit to the Director, at least 10 days prior to publication, every notice of proposed rulemaking and final rule.

(d) To permit each proposed major rule to be analyzed in light of the requirements stated in Section 2 of this Order, each preliminary and final Regulatory Impact Analysis shall contain the following information:

(1) A description of the potential benefits of the rule, including any beneficial effects that cannot be quantified in monetary terms, and the identification of those likely to receive the benefits;

(2) A description of the potential costs of the rule, including any adverse effects that cannot be quantified in monetary terms, and the identification of those likely to bear the costs;

(3) A determination of the potential net benefits of the rule, including an evaluation of effects that cannot be quantified in monetary terms;

(4) A description of alternative approaches that could substantially achieve the same regulatory goal at lower cost, together with an analysis of this potential benefit and costs and a brief explanation of the legal reasons why such alternatives, if proposed, could not be adopted; and

(5) Unless covered by the description required under paragraph (4) of this subsection, an explanation of any legal reasons why the rule cannot be based on the requirements set forth in Section 2 of this Order.

(e)(1) The Director, subject to the direction of the Task Force, which shall resolve any issues raised under this Order or ensure that they are presented to the President, is authorized to review any preliminary or final Regulatory Impact Analysis, notice of proposed rulemaking, or final rule based on the requirements of this Order.

(2) The Director shall be deemed to have concluded review unless the Director advises an agency to the contrary under subsection (f) of this Section:

(A) Within 60 days of a submission under subsection (c)(1) or a submission of a preliminary Regulatory Impact Analysis or notice of proposed rulemaking under subsection (c)(2);

(B) Within 30 days of the submission of a final Regulatory Impact Analysis and a final rule under subsection (c)(2); and

(C) Within 10 days of the submission of a notice of proposed rulemaking or final rule under subsection (c)(3).

(f)(1) Upon the request of the Director, an agency shall consult with the Director concerning the review of a preliminary Regulatory Impact Analysis or notice of proposed rulemaking under this Order, and shall, subject to Section 8(a)(2) of this Order, refrain from publishing its preliminary Regulatory Impact Analysis or notice of proposed rulemaking until such review is concluded.

(2) Upon receiving notice that the Director intends to submit views with respect to any final Regulatory Impact Analysis or final rule, the agency shall, subject to Section 8(a)(2) of this Order, refrain from publishing its final Regulatory Impact Analysis or final rule until the agency has responded to the Director's views, and incorporated those views and the agency's response in the rulemaking file.

(3) Nothing in this subsection shall be construed as displacing the agencies' responsibilities delegated by law.

(g) For every rule for which an agency publishes a notice of proposed rulemaking, the agency shall include in its notice:

(1) A brief statement setting forth the agency's initial determination whether the proposed rule is a major rule, together with the reasons underlying that determination; and

(2) For each proposed major rule, a brief summary of the agency's preliminary Regulatory Impact Analysis.

(h) Agencies shall make their preliminary and final Regulatory Impact Analyses available to the public.

(i) Agencies shall initiate reviews of currently effective rules in accordance with the purposes of this Order, and perform Regulatory Impact Analyses of currently effective major rules. The Director, subject to the direction of the Task Force, may designate currently effective rules for review in accordance with this Order, and establish schedules for reviews and Analyses under this Order.

SEC. 4. *Regulatory Review.* Before approving any final major rule, each agency shall:

(a) Make a determination that the regulation is clearly within the authority delegated by law and consistent with congressional intent, and include in the FEDERAL REGISTER at the time of promulgation a memorandum of law supporting that determination.

(b) Make a determination that the factual conclusions upon which the rule is based have substantial support in the agency record, viewed as a whole, with full attention to public comments in general and the comments of persons directly affected by the rule in particular.

SEC. 5. *Regulatory Agendas.*

(a) Each agency shall publish, in October and April of each year, an agenda of proposed regulations that the agency has issued or expects to issue, and currently effective rules that are under agency review pursuant to this Order. These agendas may be incorporated with the agendas published under 5 U.S.C. 602, and must contain at the minimum:

(1) A summary of the nature of each major rule being considered, the objectives and legal basis for the issuance of the rule, and an approximate schedule for completing action on any major rule for which the agency has issued a notice of proposed rulemaking;

(2) The name and telephone number of a knowledgeable agency official for each item on the agenda; and

(3) A list of existing regulations to be reviewed under the terms of this Order, and a brief discussion of each such regulation.

(b) The Director, subject to the direction of the Task Force, may, to the extent permitted by law:

(1) Require agencies to provide additional information in an agenda; and

(2) Require publication of the agenda in any form.

SEC. 6. *The Task Force and Office of Management and Budget.*

(a) To the extent permitted by law, the Director shall have authority, subject to the direction of the Task Force, to:

(1) Designate any proposed or existing rule as a major rule in accordance with Section 1(b) of this Order;

(2) Prepare and promulgate uniform standards for the identification of major rules and the development of Regulatory Impact Analyses;

(3) Require an agency to obtain and evaluate, in connection with a regulation, any additional relevant data from any appropriate source;

(4) Waive the requirements of Sections 3, 4, or 7 of this Order with respect to any proposed or existing major rule;

(5) Identify duplicative, overlapping and conflicting rules, existing or proposed, and existing or proposed rules that are inconsistent with the policies underlying statutes governing agencies other than the issuing agency or with the purposes of this Order, and, in each such case, require appropriate interagency consultation to minimize or eliminate such duplication, overlap, or conflict;

(6) Develop procedures for estimating the annual benefits and costs of agency regulations, on both an aggregate and economic or industrial sector basis, for purposes of compiling a regulatory budget;

(7) In consultation with interested agencies, prepare for consideration by the President recommendations for changes in the agencies' statutes; and

(8) Monitor agency compliance with the requirements of this Order and advise the President with respect to such compliance.

(b) The Director, subject to the direction of the Task Force, is authorized to establish procedures for the performance of all functions vested in the Director by this Order. The Director shall take appropriate steps to coordinate the implementation of the analysis, transmittal, review, and clearance provisions of this Order with the authorities and requirements provided for or imposed upon the Director and agencies under the Regulatory Flexibility Act, 5 U.S.C. 601 *et seq.*, and the Paperwork Reduction Plan Act of 1980, 44 U.S.C. 3501 *et seq.*

SEC. 7. *Pending Regulations.*

(a) To the extent necessary to permit reconsideration in accordance with this Order, agencies shall, except as provided in Section 8 of this Order, suspend or postpone the effective dates of all major rules that they have promulgated in final form as of the date of this Order, but that have not yet become effective, excluding:

(1) Major rules that cannot legally be postponed or suspended;

(2) Major rules that, for good cause, ought to become effective as final rules without reconsideration. Agencies shall prepare, in accordance with Section 3 of this Order, a final Regulatory Impact Analysis for each major rule that they suspend or postpone.

(b) Agencies shall report to the Director no later than 15 days prior to the effective date of any rule that the agency has promulgated in final form as of the date of this Order, and that has not yet become effective, and that will not be reconsidered under subsection (a) of this Section:

(1) That the rule is excepted from reconsideration under subsection (a), including a brief statement of the legal or

other reasons for that determination; or

(2) That the rule is not a major rule.

(c) The Director, subject to the direction of the Task Force, is authorized, to the extent permitted by law, to:

(1) Require reconsideration, in accordance with this Order, of any major rule that an agency has issued in final form as of the date of this Order and that has not become effective; and

(2) Designate a rule that an agency has issued in final form as of the date of this Order and that has not yet become effective as a major rule in accordance with Section 1(b) of this Order.

(d) Agencies may, in accordance with the Administrative Procedure Act and other applicable statutes, permit major rules that they have issued in final form as of the date of this Order, and that have not yet become effective, to take effect as interim rules while they are being reconsidered in accordance with this Order, *provided that,* agencies shall report to the Director, no later than 15 days before any such rule is proposed to take effect as an interim rule, that the rule should appropriately take effect as an interim rule while the rule is under reconsideration.

(e) Except as provided in Section 8 of this Order, agencies shall, to the extent permitted by law, refrain from promulgating as a final rule any proposed major rule that has been published or issued as of the date of this Order until a final Regulatory Impact Analysis, in accordance with Section 3 of this Order, has been prepared for the proposed major rule.

(f) Agencies shall report to the Director, no later than 30 days prior to promulgating as a final rule any proposed rule that the agency has published or issued as of the date of this Order and that has not been considered under the terms of this Order:

(1) That the rule cannot legally be considered in accordance with this Order, together with a brief explanation of the legal reasons barring such consideration; or

(2) That the rule is not a major rule, in which case the agency shall submit to the Director a copy of the proposed rule.

(g) The Director, subject to the direction of the Task Force, is authorized, to the extent permitted by law, to:

(1) Require consideration, in accordance with this Order, of any proposed major rule that the agency has published or issued as of the date of this Order; and

(2) Designate a proposed rule that an agency has published or issued as of the date of this Order, as a major rule in accordance with Section 1(b) of this Order.

(h) The Director shall be deemed to have determined that an agency's report to the Director under subsections (b), (d), or (f) of this Section is consistent with the purposes of this Order, unless the Director advises the agency to the contrary:

(1) Within 15 days of its report, in the case of any report under subsections (b) or (d); or

(2) Within 30 days of its report, in the case of any report under subsection (f).

(i) This Section does not supersede the President's Memorandum of January 29, 1981, entitled "Postponement of Pending Regulations", which shall remain in effect until March 30, 1981.

(j) In complying with this Section, agencies shall comply with all applicable provisions of the Administrative Procedure Act, and with any other procedural requirements made applicable to the agencies by other statutes.

SEC. 8. *Exemptions.*

(a) The procedures prescribed by this Order shall not apply to:

(1) Any regulation that responds to an emergency situation, *provided that,* any such regulation shall be reported to the Director as soon as is practicable, the agency shall publish in the FEDERAL REGISTER a statement of the reasons why it is impracticable for the agency to follow the procedures of this Order with respect to such a rule, and the agency shall prepare and transmit as soon as is practicable a Regulatory Impact Analysis of any such major rule; and

(2) Any regulation for which consideration or reconsideration under the terms of this Order would conflict with deadlines imposed by statute or by judicial order, *provided that,* any such regulation shall be reported to the Director together with a brief explanation of the conflict, the agency shall publish in the FEDERAL REGISTER a statement of the reasons why it is impracticable for the agency to follow the procedures of this Order with respect to such a rule, and the agency, in consultation with the Director, shall adhere to the requirements of this Order to the extent permitted by statutory or judicial deadlines.

(b) The Director, subject to the direction of the Task Force, may, in accordance with the purposes of this Order, exempt any class or category of regulations from any or all requirements of this Order.

SEC. 9. *Judicial Review.* This Order is intended only to improve the internal management of the Federal government, and is not intended to create any right or benefit, substantive or procedural, enforceable at law by a party against the United States, its agencies, its officers or any person. The determinations made by agencies under Section 4 of this Order, and any Regulatory Impact Analyses for any rule, shall be made part of the whole record of agency action in connection with the rule.

SEC. 10. *Revocations.* Executive Orders No. 12044, as amended, and No. 12174 are revoked.

RONALD REAGAN

The White House,
February 17, 1981.

[Filed with the Office of the Federal Register, 3:19 p.m., February 17, 1981]

SELECTED READINGS

NEW ECONOMIC TECHNIQUES

federal register

Wednesday
April 7, 1982

Part III

Environmental Protection Agency

Emissions Trading Policy Statement; General Principles for Creation, Banking, and Use of Emission Reduction Credits

ENVIRONMENTAL PROTECTION AGENCY

[PRM-FRL-1994-5]

Emissions Trading Policy Statement; General Principles for Creation, Banking, and Use of Emission Reduction Credits

May 12, 1982.

AGENCY: Environmental Protection Agency.

ACTION: Proposed policy statement and accompanying technical issues document.

SUMMARY: It is the policy of EPA to encourage use of emissions trades to achieve more flexible, rapid and efficient attainment of national ambient air quality standards.

This Policy Statement describes emissions trading, sets out general principles EPA will use to evaluate emissions trades under the Clean Air Act, and expands opportunities for states and industry to use these less-costly control approaches. Emissions trading includes several alternatives to traditional regulation: bubbles, netting, and offsets, as well as banking (storage) of emission reduction credits (ERCs) for future use. These alternatives do not alter existing air quality requirements; they simply give states and industry more flexibility to meet these requirements. EPA endorses emissions trading and supports its accelerated use by states and industry to meet the goals of the Clean Air Act more quickly and inexpensively.

This Policy Statement replaces the original bubble policy (44 FR 71779, Dec. 11, 1979) and sets forth minimum legal requirements for creation, storage or use of emission reduction credits in any emissions trade. It also provides criteria for "generic" SIP rules under which states can approve bubble or other trades without case-by-case federal SIP review.

EPA encourages states to continue adopting generic trading rules and approving individual trades. Until EPA takes final action on this proposal, it will evaluate state actions under the principles set forth here and illustrated in the accompanying Technical Issues Document.

EFFECTIVE DATE: This Policy Statement is effective as interim guidance upon publication. The deadline for submitting written comments is July 6, 1982.

ADDRESSES: Comments should be sent in triplicate if possible to: Central Docket Section (A-130), U.S. Environmental Protection Agency, Washington, D.C. 20460, Attn: Doc. No. G-81-2.

DOCKET: EPA has established docket number G-81-2 for this action. This docket is an organized and complete file of all significant information submitted to or otherwise considered by EPA. The docket is available for public inspection and copying between 8:00 a.m. and 4:00 p.m., Monday through Friday, at EPA's Central Docket Section. A reasonable fee may be charged for copying.

FURTHER INQUIRIES:

Ivan Tether, Regulatory Reform Staff (PM-223), U.S. Environmental Protection Agency, 401 M Street, SW., Washington, D.C. 20460, (202) 382-2785,

or

Leo Stander, Office of Air Quality Planning and Standards (MD-15), Research Triangle Park, North Carolina 27711, (919) 541-5516.

SUPPLEMENTARY INFORMATION: Under Executive Order 12291, EPA must judge whether this action is "major" and therefore subject to the requirement of a Regulatory Impact Analysis. This action is not major because it establishes policies that are voluntary and can substantially reduce costs of complying with the Clean Air Act. Furthermore, it can reduce administrative complexity by reducing the number of trades which must be approved by EPA, can stimulate innovation in pollution control, and can allow state and local pollution control agencies to conserve scarce resources.

This Policy Statement was submitted to the Office of Management and Budget for review. Any comments from OMB to EPA are available for public inspection in Docket G-81-2. Pursuant to 5 U.S.C. 605(b), I hereby certify that this action will not have a significant economic impact on a substantial number of small entities. As a policy designed to allow firms flexibility and to reduce administrative complexity, it will impose no burdens on either small or large entities.

I. Introduction: Components of Emissions Trading

This statement details EPA policy on emissions trading. It presents the minimum conditions EPA considers necessary for emissions trades to satisfy the Clean Air Act. It simplifies past requirements and expands opportunities to use these more efficient alternatives.

A. What Is Emissions Trading?

Emissions trading consists of bubbles, netting, emission offsets, and emission-reduction banking. These alternatives involve the creation of surplus reductions at certain emission sources and use of these reductions to meet requirements applicable to other emission sources. Emission trades can provide more flexibility, and may therefore be used to reduce control costs, encourage faster compliance, and free scarce capital for industrial revitalization. Moreover, by developing "generic" trading rules (see section III below) states[1] and industry can be excused from SIP revisions, and attendant delay and uncertainty, for many individual bubbles or other trades.

B. The Bubble Policy and Today's Improvements

EPA's bubble policy lets *existing* plants (or groups of plants) decrease or be excused from pollution controls at one or more emissions sources in exchange for compensating increases in control at other emission sources. Bubbles give plant managers flexibility to develop less costly ways of meeting air quality requirements. Each bubble must be equivalent to the original emission limits in terms of ambient impact and enforceability. Bubbles cannot be used to meet technology-based requirements applicable to new sources.

This Policy Statement replaces the original bubble policy (Dec. 11, 1979; 44 FR 71779) and broadens opportunities for the bubble's use. Major changes include:

- Authorizing generic trading rules for all criteria pollutants;
- Extending use of the bubble to areas which lack approved demonstrations of attainment of the national ambient air quality standards;
- Expanding opportunities for use of bubbles as an alternative means of meeting reasonably available control technology (RACT) requirements;
- Reducing unnecessary requirements for detailed air quality modeling of the ambient impact of each trade;
- Reducing unnecessary constraints on trades involving open dust sources of particulate emissions;
- Allowing VOC and CO sources more time to implement bubbles under administrative compliance schedules, consistent with reasonable further progress and statutory deadlines for attaining ambient standards;
- Allowing sources to use the bubble to come into compliance, instead of having to be on a compliance schedule with original SIP limits to be eligible to bubble; and

---

[1] "States" includes any entity properly delegated authority to administer relevant parts of a State Implementation Plan (SIP) under the Clean Air Act.

- Allowing broader use of emission reductions from shutdowns.

These and other changes are explained below and in the accompanying Technical Issues Document.

C. Netting

Netting removes the burden of new source review requirements from plants expanding or modernizing in PSD and nonattainment areas, so long as any increase in plant-wide emissions is insignificant. By "netting out" of review the new facility may be exempted from preconstruction permits and associated requirements, including monitoring and modeling, installation of BACT or LAER control technology, the offset requirement, and applicable bans on new construction. The new facility must still meet emission limits established by new source performance standards (NSPS) under Section 111 of the Clean Air Act. Rules governing netting for sources in attainment (PSD) areas were published on August 7, 1980 (45 FR 52676) and rules for nonattainment areas were expanded on October 14, 1981 (46 FR 50766).

D. Emission Offsets

In nonattainment areas, new major stationary sources and modifications may be required to secure sufficient surplus emission reductions to more than "offset" their increased emissions. This requirement is designed to permit industrial growth in nonattainment areas while improving air quality. It is currently implemented by rules published at 40 CFR 51.18(j) and 51.18 (Appendix S), as amended by 45 FR 52676 (August 7, 1980) and 46 FR 50766 (October 14, 1981).

E. Emission Reduction Banking

Banking lets firms store qualified emission reductions for later use in bubble, netting or offset transactions. Banked emission reduction credits (ERCs) can also be sold to firms seeking alternate ways to meet regulatory requirements more quickly flexibly.

EPA's revised offset ruling (40 CFR 51.18, Appendix S) authorized states to establish banking rules as part of their SIPs. This Policy Statement and the Technical Issues Document are EPA's first detailed articulation of the necessary components of a complete state banking rule under the Clean Air Act.

F. Effect of This Policy Statement

Emissions trading is voluntary. States are free to adopt generic rules or let trades continue to be implemented as individual SIP revisions. They may adopt rules which incorporate all or any combination of these trading approaches.

EPA is issuing this Policy Statement as a proposal because elements of emissions trading, particularly banking, raise issues which have not yet been subject to public comment. EPA urges interest parties to address all relevant issues in their comments.

However, until final action the Agency intends to use the principles in this Statement to evaluate trading activities which become ripe for decision, including state adoption of generic bubble and banking rules. Many states are now implementing such rules and should continue to do so.

This Policy Statement is accompanied by a Technical Issues Document for use by states and industry in further understanding emissions trading. The Document offers more detail on minimum requirements and available options under the Clean Air Act. EPA also invites comment on any aspect of the Technical Issues Document.

This notice reflects the current Clean Air Act and existing regulations. A Policy Statement cannot legally alter such requirements. However, it establishes EPA policy in areas not governed by applicable regulations and sets out general principles which states and industry may use to apply those regulations in individual cases. Pending litigation or future rulemaking may alter the general principles outlined here and reflected in the Technical Issues Document. Future federal or state rulemaking, such as additional RACT requirements or changes in ambient standards, may also affect firms that have engaged in emissions trading activities.

II. Minimum Legal Requirements for Creating, Using, and Banking Emission Reduction Credits [2]

A. Creating Emission Reduction Credits

Emission reduction credits (ERCs) are the common currency of all trading activity. To assure that emissions trades do not contravene relevant requirements of the Clean Air Act, only reductions which are *surplus*, *enforceable*, *permanent*, and *quantifiable* can qualify as emission reduction credits and be banked or used in an emissions trade.

1. *Surplus:* Only emission reductions not currently required by law can be considered surplus. To define what is surplus, the state must first establish an appropriate emissions baseline against which surplus reductions can be calculated.

In nonattainment areas with approved demonstrations of attainment, the baseline must be consistent with assumptions used to develop the area's SIP. Only reductions not assumed in the area's demonstration of reasonable further progress and attainment can be considered surplus. This generally means that actual emissions must be the baseline where actual emissions were used for such demonstrations, and that allowable emissions may be the baseline where allowable emissions were used for such demonstrations.

In nonattainment areas lacking a demonstration of attainment, states may use a variety of baselines which do not jeopardize attainment by statutory deadlines. In general, states may use as baselines either actual emissions (with source commitment to future reductions if needed for attainment) or emission levels which reflect reasonably available control technology. However, where such areas must attain primary ambient air quality standards by December 1982, baselines reflecting reasonably available control technology for emission sources involved in the trade must be used.

In attainment areas, to be consistent with air quality requirements established in prevention of significant deterioration (PSD) programs under Section 110 and Part C of the Clean Air Act, actual emissions would normally be the baseline. States may use allowable emissions as the baseline, if proper consideration of increment consumption is assured.

2. *Enforceable:* To assure that Clean Air Act requirements are met, each transaction must be approved by the state and be enforceable. Enforceable emission limits may be created through SIP revisions (see Section IV), under generic trading rules (see Section III), through new source construction permits, or through state permits issued under 40 CFR 51.18, among other ways.

3. *Permanent:* Only permanent reductions in emissions can qualify for credit. Permanence can generally be assured by requiring changes in source permits to reflect a reduced level of permissible emissions.

4. *Quantifiable:* Emission reductions must be quantifiable in terms of both *measuring* the amount of the reduction

---

[2] Because this Policy Statement and accompanying Technical Issues Document reflect general Clean Air Act principles, states and individual sources are free to show that a general principle does not apply to particular circumstances or could be satisfied using approaches other than those described. States and sources have this option under current law, and nothing in this Policy Statement or the accompanying Technical Issues Document restricts their opportunity to make such showings.

and *charcterizing* that reduction for future use. Quantification may be based on emission factors, stack tests, monitored values, operating rates and averaging times, process or production inputs, modeling, or other reasonable measurement practices. The same method of calculating emissions should generally be used to quantify emission levels before and after the reduction.

B. Using Emission Reduction Credits

ERCs may be used by sources in bubble, netting, or offset transactions. The general principles below will assure that all uses of ERCs are consistent with ambient attainment and maintenance considerations under the Clean Air Act.

1. *Emissions trades must involve the same criteria pollutant.* An emission reduction may only be traded against an increase in the same criteria pollutant. For example, only reductions of particulates can be substituted for increases of particulates, reductions of VOCs for increases in VOCs.

2. *All uses of ERCs must satisfy applicable ambient tests.* the Clean Air Act requires that all areas throughout the country attain and maintain national ambient air quality standards. The ambient effect of a trade depends on the dispersion characteristics of the pollutant involved. Ambient considerations will generally not affect trades involving VOC or NO_x, whose impacts occur across broad geographic areas. For these pollutants "pound for pound" trades may be treated as equal in ambient effect. However, dispersion characteristics are important for bubble and offset trades of SO_2, TSP, or CO whose ambient impact may vary with where the emission increases and decreases occur. Trades of these pollutants must demonstrate equivalent ambient impact under the three-tiered modeling screen discussed in the Technical Issues Document or under a similar approach.

3. *Trades should not increase hazardous pollutants.* Except as may be specifically permitted by future national emission standards for hazardous air pollutants (NESHAPs), a source may not use a bubble to meet NESHAPs requirements or increase emissions beyond the levels they prescribe. Where a significant fraction of a criteria pollutant stream has been listed under Section 112 but not yet regulated, the hazardous emissions involved in the trade should either remain equal or should decrease (i.e., be traded down).

4. *Emission trades cannot be used to meet applicable technology-based requirements.* New or expanding sources cannot use ERCs to meet new source performance standards, best available control technology requirements in PSD areas, or lowest achievable emission rate control technology requirements in nonattainment areas.

5. *States may allow bubbles in areas without approved demonstrations of attainment.* States are authorized to approve bubbles in such areas, so long as timely attainment of air quality standards will not be jeopardized. (See Section II.A above and the Technical Issues Document).

6. *Sources may use the bubble to achieve compliance.* States may allow sources to use a bubble to achieve rapid compliance once applicable emission limits and deadlines are established as part of a bubble application. States need not require sources to develop and go forward with detailed plans (including ordering equipment) to meet original emission limits when new limits which will supercede them are pending under a bubble application.

7. *States may extend certain compliance schedules.* States may give sources more time to implement bubbles by granting compliance extensions as part of approvals under generic rules, where (i) the area has received an attainment extension under Section 172(a)(2) of the Clean Air Act (applicable to VOC or CO); and (ii) the total amount of reductions required to satisfy the state's reasonable further progress demonstration will not be reduced for each year in question. States may grant similar compliance extensions for VOC or CO bubbles approved as individual SIP revisions subject to (i) above, provided the extension is consistent with reasonable further progress requirements (See section IV below).

8. *States may approve bubbles involving open dust sources of particulate emissions, based on modeling demonstrations.* This action reduces past restrictions on trades involving open dust sources of particulate emissions. Such trades may be approved based on acceptable modeling and/or monitoring demonstrations, provided sources agree to post-approval monitoring to determine if predicted air quality results have been realized.

C. Banking Emission Reduction Credits

Only emission reductions that are surplus, permanent, enforceable, and quantifiable can be banked. To provide maximum protection for sources and avoid future legal problems, state banking rules should specify the ownership rights established, the types of sources eligible to bank ERCs, and any additional conditions placed on certifying, holding, or using banked ERCs.

As a legal minimum, state banking rules must establish ownership rights which are consistent with Clean Air Act requirements, including the requirement that SIPs provide for attainment and maintenance of ambient air quality standards "as expeditiously as practicable." States have considerable latitude in meeting this requirement, and may guarantee banked ERCs against any ambient-based reduction in quantity, so long as that guarantee does not interfere with reasonable further progress and attainment should ambient standards change or additional emission reductions be required.

In most states banking will be an extension of ongoing permit activities. The state or its designee will accept and evaluate requests to certify an ERC, maintain a publicly available ERC registry or similar instrument describing the quantity and types of banked credits, and track transfers and withdrawals of ERCs.

III. State Generic Trading Rules

Use of emission reduction credits under state generic rules approved by EPA will not require individual SIP revisions. The Technical Issues Document explains acceptable generic rules and procedures which states may adopt to reduce the need for individual SIP revisions.

Emissions trades can be approved without SIP revisions if evaluated under EPA-approved state procedures that assure no trade will interfere with timely attainment and maintenance of ambient standards. State generic rules are approvable only if their procedures are sufficiently replicable in operation to meet this test. By approving the generic rule, EPA approves in advance an array of acceptable emission limits, and no further case-by-case federal approval is required for individual trades developed under the rule.

Any trade under a generic rule will involve emission increases at some sources and emission decreases at others. For trades to be approvable under a generic rule, the sum of these increases and decreases (i.e., applicable net baseline emissions) must be zero or less. States may adopt generic rules which exempt from individual SIP revisions: (1) *de minimis* trades whose sum of the emission increases, looking only at the increasing sources, totals less than 100 tons per year after applicable control requirements; (2) trades involving VOC or NO_x emissions (3) trades between SO_2 sources, between CO sources, or between TSP sources, provided those sources are located in the same immediate vicinity and emissions do not increase at the source with the lower effective plume height; and (4) other SO_2, CO or TSP trades which do not increase emissions and for which carefully defined use of a screening model predicts no significant increase in ambient concentrations. EPA encourages states to adopt such rules or develop alternative approaches that equally assure attainment and maintenance of ambient standards.

To the extent state procedures for rulemaking or permit changes do not assure reasonable public notice and opportunity for comment on proposed trades, states should incorporate such provisions as part of their generic rules.

IV. Trades Not Covered by Generic Rules

States and sources may continue to use the SIP revision process to implement trades which are not covered by a generic rule. Because the SIP revision process can take account of many more individual variations, trades which could not be accomplished under a generic rule may still be implemented as site-specific SIP revisions.

EPA will take action on generic rules and individual trades submitted as SIP revisions as quickly as possible after a state has adopted a SIP revision and submitted the action to EPA. EPA encouages "parallel processing" of such revisions, with EPA and the state conducting concurrent review so that both agencies can propose and take final action at roughly the same time. EPA will also publish noncontroversial SIP revisions as immediate final actions, converting them to proposals only if requests to submit comments are received within 30 days (see 46 FR 44477; Sept. 4, 1981).

V. Conclusion

This Policy Statement sets out basic principles for individual trades and approvable generic trading rules. EPA encourages states to use these principles as a framework and refer to the accompanying Technical Issues Document for further discussion and examples. States are encouraged to design other rules which satisfy these principles but meet their specific needs.

As a policy statement, this notice does not establish conclusively how EPA will resolve issues in individual cases. EPA will accept public comment on this proposal as well as on specific SIP changes submitted under it, and will review individually each generic rule and those emissions trades submitted as SIP revisions to determine their acceptability under the Clean Air Act. Interested parties will have full opportunity to scrutinize application of these general principles to specific cases, and to seek subsequent judicial review of such cases, when particular generic rules or individual trades are proposed and approved.

This Statement expands opportunities to use emissions trading. If implemented by states it can allow industry to use the bubble and other trading approaches in additional circumstances and geographic areas. The policy will also reduce adversary tensions, allow states to benefit from industrial knowledge, and encourage quicker compliance, while reducing unnecessary federal review. It represents important regulatory reform, for states as well as industry, by encouraging greater flexibility in meeting air quality goals.

Dated: April 2, 1982.

Anne M. Gorsuch,

Administrator.

Emissions Trading: Technical Issues Document

TABLE OF CONTENTS

I. Components of Emissions Trading

A. Creating Emission Reduction Credits

1. All Reductions Must Be Surplus
2. Alternative Emission Limits Must Be Enforceable
3. All Reductions Must Be Permanent
4. All Reductions Must Be Quantifiable

B. Using Emission Reduction Credits

1. Substantive Principles for Using ERCs
   a. Emission Trades Must Involve the Same Pollutant
   b. All Uses of ERCs Must Satisfy Ambient Tests
   c. Trades Should Not Increase Net Baseline Emissions
   d. Trades Should Not Increase Hazardous Emissions
   e. Trades Cannot Be Used to Meet Technology-Based Requirements
   f. Trades Involving Open Dust Emission Sources
2. Procedural Steps for Using ERCs
   a. Bubbles Can Be Used to Achieve Compliance
   b. Extensions of Compliance Deadlines
   c. Pending Enforcement Actions

C. Banking Emission Reduction Credits

1. Rules Must Designate Administering Agency
2. Only ERCs May Be Banked
3. Procedures for Banking
4. Banking Rules Must Establish Ownership Rights
5. Rules Must Establish An ERC Registry
6. Possible Enforcement Adjustments to ERCs
7. Possible Ambient Adjustment to ERCs

II. Trades Covered by Generic Rules

A. General Principles for Evaluating Generic Rules

B. Scope of Generic Rules

C. Applicability To Process Fugitive and Open Dust Trades

D. Enforcing Emission Limits Under Generic Rules

E. EPA Oversight of Trades Under Generic Rules

F. Public comment

III. Trades not Covered by Generic Rules

Appendix: Regional EPA Emissions Trading Coordinators

Emissions Trading: Technical Issues Document

This Document offers more detail on technical issues for firms and pollution control agencies seeking to implement individual emission trades or generic trading rules that meet the principles in EPA's Emissions Trading Policy Statement.[1] It describes both the minimum legal requirements for emissions trades under the Clean Air Act, and a range of legal options which states [2] may consider. States and industry are encouraged to pursue other approaches consistent with those discussed here.

Emissions trading is voluntary. States may implement emissions trades on a case-by-case basis or develop generic trading rules covering one or more classes of transactions. Trades under approved generic rules will be exempt from individual SIP revisions. Such rules can also provide greater certainty by specifying which trades are quickly approvable.

Section I of this Document explains general legal principles governing all emissions trading. Section II explains principles governing state generic rules. Section III discusses special considerations for emission trades implemented as individual SIP revisions.

Because these sections reflect general Clean Air Act principles, states and individual sources remain free to show that a general principle does not apply to particular circumstances or can be satisfied using another approach. States and sources have this option under current law, and nothing in the Policy Statement or this Document restricts their opportunity to make such showings. (See Section III below).

---

[1] Emissions trading was formerly known as "controlled trading".

[2] "States" includes any entity properly delegated authority to administer relevant parts of a State Implementation Plan (SIP) under the Clean Air Act.

I. Components of Emissions Trading

The components of any emissions trade are the *creation* of an emission reduction credit (ERC), its *use* in a trade, and its possible *storage* in a bank.

A. Creating Emission Reduction Credits

States may grant credit only to those emission reductions that are *surplus, enforceable, permanent*, and *quantifiable*. Otherwise use of ERCs might degrade air quality, threaten the viability of the area's SIP, and result in more stringent controls.

1. *All Reductions Must Be Surplus.* Only surplus reductions not currently required by law can be substituted for required reduction as part of an emissions trade without jeopardizing air quality goals.

The first step in qualifying a reduction as "surplus" is to establish a level of baseline emissions. The baseline identifies the level of required emissions beyond which reductions must occur for a source to receive credit. It will generally be determined by whether the area is attainment or nonattainment, and by the way the state developed its SIP.

a. *Use of Actual or Allowable Emissions as the Baseline.* In *attainment areas* the baseline will generally be actual emissions—only reductions below a source's actual level of historical emissions can be considered surplus. Because current regulations specify actual air quality as the basis for determining increment consumption, these rules normally require that actual emissions be used for the area's maintenance strategy. (See 45 FR 52717; Aug. 7, 1980). However, allowable emissions may be used as the baseline if proper consideration is given to increment usage.

In *nonattainment areas* the baseline may be either maximum allowable emissions or actual historical emissions.[3] To determine which baseline is appropriate, the state should examine the assumptions used in developing its demonstration of attainment.

In *nonattainment areas which used allowable emissions as the basis for their attainment strategy*, sources can use their SIP allowable limits as the baseline for creating ERCs. Many states used allowable limits in developing their SO$_2$ and TSP attainment plans.

Other nonattainment areas used inventories that were either substantially deficient or based on actual emissions, or they relied on measured (and therefore "actual") ambient values as the primary basis for determining SIP emission limits needed to demonstrate attainment. Under current EPA regulations, in these areas some level of actual historical emissions would generally be the baseline. *However*, these areas may approve use of allowable emissions as the baseline on a case-by-case basis, where that use comports with reasonable further progress and the source shows it will neither create a new ambient violation nor prevent the planned removal of an existing violation. (See Section III)

b. *Surplus Reductions in Areas Lacking Approved Demonstrations.* In several jurisdictions demonstrations of attainment are not yet complete. Some of these jurisdictions are uncertain where to secure sufficient emission reductions; others have not yet adopted enforceable emission limits based on reasonably available control technology (RACT) for specific industrial processes. Additional emission controls on these or other sources generally are needed to reach attainment. The question is how "surplus" should be defined for sources lacking SIP-defined RACT emission limits in these areas. Where RACT is already defined in the SIP, it will of course be the baseline. Where RACT for relevant source categories has not been defined, credit for surplus reductions may be granted in at least two general ways which are consistent with Clean Air Act requirements for reasonable further progress and attainment.

(i) *Use of a RACT Baseline.* If RACT has not been defined in the SIP, the source may agree with the State and EPA to an acceptable RACT limit for the emission sources involved in the trade. A surplus would then consist of any emission reductions in excess of those required to meet RACT. Where sources voluntarily agree to such a RACT level, EPA encourages states not to reexamine the agreed-upon individual emission levels for a period of time consistent with the statutory deadlines for attainment, unless there is no other practical way to satisfy requirements of the Clean Air Act.

A RACT baseline is the only option in areas that will not attain the relevant primary ambient standard by December 1982 and have not received attainment extensions for such standard. Because of the extremely short time period remaining for attainment and the practical difficulty of securing further reductions prior to the December 1982 deadline, this limitation is necessary to assure that trades in these areas comport with the statutory deadline and the mandate for RACT "as expeditiously as practicable."

(ii) *Use of Actual Emissions Baseline.* Areas that will not attain the primary ozone or CO ambient standard by December 1982, but have received attainment extensions until 1987, as well as areas with plans that will attain the primary (but not the secondary) TSP or SO$_2$ ambient standard by December 1982, may use current actual emissions (or "old" Section 110 SIP limits if applicable) as the baseline. Under this option, sources in these areas could trade using individual emission sources not yet subject to RACT limits, so long as states clearly advise sources of their responsibility to find or produce reductions equivalent to future RACT requirements if and when the state imposes them and sources commit to meet these future requirements. This would give industry flexibility to create and use ERCs at the earliest date. It would also avoid having to negotiate individual RACT baselines through case-by-case SIP revisions.

States that choose not to rquire negotiated RACT baselines should be aware that their SIPs must still comply with Section 172(b)(2), which requires imposition of RACT "as expeditiously as practicable."

C. *No Double-Counting of Reductions.* To be considered surplus, an emission reduction cannot already have been included as part of the area's baseline emissions. Double-counting of reductions—granting credit for the same emission reduction, once to the state and a second time to a source for use in an emissions trade—must be addressed in the following situations.

(i) *Crediting Pre-Existing Emission Reductions.* In *nonattainment areas* credit generally cannot be granted for emission reductions made before nonitoring data was collected for use in SIP planning. Because monitored ambient levels may have *already* reflected these emission decreases, they would have been assumed in calculating the reductions needed to attain ambient standards. States should clearly identify in their rules the date before which reductions will not qualify for credit. The earliest acceptable baseline date would normally be the year of the most recent emission inventory or monitoring data used in planning Part D SIP revisions under the Clean Air Act Amendments of 1977.

In *attainment areas* emission reductions that occurred before the PSD emissions baseline was established generally cannot qualify for credit. States have already assumed these reductions in their PSD baselines. If credited and later used, they could undermine the area's strategy to maintain air quality.

---

[3] See, 45 FR 52729 (Aug. 7, 1980). Several aspects of EPA's August 7th regulations, including the definition of baseline, are currently under judicial review. Any rulemaking changes which result from that litigation may be controlling here.

(ii) *Crediting Reductions From Shutdowns.* In general, a state may credit reductions from shutdowns for *bubble trades* if the SIP has not already assumed credit for these reductions in its attainment strategy. So long as reductions from shutdowns have not already been counted in developing an area's attainment strategy, they are an appropriate source of surplus reductions for bubble trades.

Many SIPs assumed a set quantity of reductions from new plant openings and existing plants shutdowns. These SIPs incorporated into their attainment strategy a net "turnover" reduction in emissions because new sources are generally cleaner than those that shut down. Double-counting would occur if a specific source received credit for reductions from such a shutdown, since that reduction was already assumed in the SIP's demonstration of attainment.

States have at least three options to grant sources credit without this kind of double-counting. *First,* they may re-examine any "turnover" credits in their SIP and decide not to take credit for these reductions. *Alternatively,* they may allow credit only after the total quantity of shutdown reductions assumed in the SIP has occurred. *Finally,* they may allow credit for a percentage of the total emission reductions realized from a shutdown, if they can show that such credit is consistent with the SIP's demonstration of attainment and reasonable further progress.

d. *Multiple Use of ERCs.* Once surplus reductions are credited, states should guard against their multiple use. In general, the same ERCs must not be banked by two different entities or used to satisfy two different regulatory requirements at the same time. To prevent these results, states should adopt an ERC registry or equivalent means of accounting for the creation, banking, transfer, or use of all ERCs. (See Section I.C.5)

e. *Reductions from Uninventoried Sources.* Sources not included in an area's SIP emission inventory may apply for credit. In general, so long as granting credit for reductions from these sources will not jeopardize an area's demonstration of attainment or reasonable further progress, there are no legal restrictions on such credits.

In *attainment areas,* all sources, regardless of whether they have been included in an inventory, may create ERCs using actual emissions as the baseline. Those emissions need only have been included in the area's PSD baseline.

In *nonattainment areas,* whether sources not on the inventory can create ERCs will turn on how the SIP's demonstration of attainment was designed.

Some areas first monitored ambient values to determine required SIP reductions, then required a proportionate reduction in emissions from certain source categories in order to attain. These areas may grant credit for reductions from uninventoried sources in at least three ways. *First,* they could required the source to use a RACT baseline and grant credit only for reductions below that baseline. *Alternatively,* they could require the same percentage reductions as imposed on inventoried sources, and grant credit only for reductions in excess of that amount. *Finally,* where no demonstration of attainment exists, they may use either a negotiated RACT baseline or (in appropriate circumstances) an actual emissions baseline. (See Section I.A.1.B above)

Other areas developed SIP demostrations based on ambient air quality models rather than area-wide proportionate reductions. To the extent these DIPs demonstrated ambient attainment through reductions required from inventoried sources, reductions from sources not on the inventory can be credited using actual emissions as the baseline.

2. *Alternative Emission Limits Must Be Enforceable. Each bubble, netting, offset or banking transaction must be enforceable and must approved by the state. Under current EPA regulations reductions used in bubble, offset and netting trades must be federally enforceable.*[4] This requirement for enforceability can generally be satisfied either through existing procedures (including individual SIP revisions or state permits issued under 40 CFR 51.18) or through generic rules, since any enforceable compliance instrument imposing emission limits within the scope of a generic rule is deemed part of the SIP.

Emission limits estalished by a trade maust also be incorporated in a compliance instrument which is legally binding and practicably enforceable. *Trades involving individual SIP revisions* automatically satisfy this requirement.

For *trades under generic rules,* a compliance instrument could take the form of an agreement between the source and state, and operating or preconstruction permit, or a consent decree. Many State permits and permit procedures may need revisions to assure that they provide adequate compliance information. However, such revisions need only occur on a case-by-case basis as individual trades are approved.

Compliance instruments should assure that enforcement officials do not have to test simultaneously every emission source involved in a trade. This generally means source-specific emission limits. However, states may use an overall emission limit that applies to a group of emission sources which can be monitored sumultaneously. This will generally require a reliable method of determining compliance through production records, input factors, or similar indirect means. (See 45 FR 80824; Dec. 8, 1980)

The compliance instrument should also specify applicable restrictions on hours of operation, production rates or input rates; enforceable test methods for determining compliance; and necessary recordkeeping or reporting requirements. To be enforceable, these limits must state the minimum time period over which they will be averaged (e.g., lbs/hour, lbs/MMBtu averaged over 24 hours, production rate/day).

3. *All Emission Reductions Must Be Permanent.* An emission reduction credit must be a permanent reduction in the level of pollution emitted by a source. Use of an ERC which is not permanent could adversely affect air quality by allowing increased emission from both the source creating the ERC and the source where it is used.[5]

To receive credit for reductions in operations (e.g., a reduction from 3 to 2 workshifts), a source must have its permit or other compliance instruction altered to reflect the curtailment in production. Future increases in production beyond the permit amount would generally require compensating emission reductions.

---

[4] In July 1981 EPA administratively stayed certain rules relating to federal enforceability requirements for netting and offsets. 46 FR 36695 (July 15, 1981). This stay has expired and has not been renewed. Requirements of existing regulations accordingly remain applicable.

[5] As an alternative, states may allow trades whose emissions increases and emissions decreases are equal in duration rather than strictly permanent. This is the minimum legal requirement under the Clean Air Act, but may require states to track trades over time to assure ambient equivalence.

Permanence may present special but resolvable problems for reductions from small sources not subject to permitting, offset requirements, or [illegible] production constraints. States which grant credit from these source categories should address the possibility that reductions from one source may be followed by equal or greater increases from similar sources in adjacent areas.

4. *All Reductions Must Be Quantifiable.* Before an emission reduction can be credited it must be quantified. This generally means the state must establish a reliable basis for *Measuring the amount and rate* of the reduction and *describing its characteristics.*

a. *Measuring the Reduction.* To quantify ERCs, emissions must be calculated both before and after the reduction. Although many different methods of calculation are available (e.g., emission factors, stack tests, monitored values, production or process inputs), the same method and averaging time should generally be used to quantify emissions before and after the reduction.

b. *Describing the Reduction.* If an ERC is to be used at the time of creation, only characteristics necessary to evaluate that proposed use need be described. Where the ERC is to be banked and its eventual use is not yet known, a more detailed description is advisable.

B. Using Emission Reduction Credits

This section explains the substantive and procedural principles applicable to use of ERCs in bubble, netting or offset transactions.

1. *Substantive Principles for Using ERCs.*

a. *Emissions Trades Must Involve the Same Pollutant.* The Clean Air Act requires states to develop separate plans to attain and maintain the national ambient air quality standard for *each* criteria pollutant. Thus, all individual bubble, netting or offset cases must involve the same pollutant. Only reductions of particulates can substitute for increases of particulates, reductions of SO_2 for increases in SO_2, etc.

b. *All Uses of ERCs Must Satisfy Ambient Tests.* The Clean Air Act requires that all areas throughout the country attain and maintain ambient standards. In *nonattainment areas,* use of ERCs cannot create a new violation of an ambient standard or prevent the planned removal of an existing violation. In *attainment areas,* use of ERCs cannot violate an increment or ambient standard. The ambient effect of a trade generally depends on the dispersion characteristics of the pollutant involved.

VOC or NO_x Trades. Ambient considerations will not affect trades involving VOC or NO_x, whose impacts occur across broad geographic areas. Within such areas one ton of decreased emissions is generally equivalent in ambient effect to one ton of increased emissions, since the precise location of those increases and decreases ordinarily does not matter. For these pollutants, "pound for pound" trades may be treated as equal in ambient effect.

TSP, SO_2 or CO Trades. Ambient considerations are critical for trades involving SO_2, particulates, or carbon monoxide, whose air quality impact may vary with where the emission increases and decreases occur. One hundred tons of ERCs for these pollutants created at one site may balance the ambient impact of a 100-ton increase at a site nearby, but may only balance the effect of an 80-ton increase at a site further away. In addition to distance between sources, plume parameters, pollutant characteristics, meterology, and topography will also affect the ambient impact of such a trade.

As a general principle, bubble applications must demonstrate ambient "equivalence" and offset transactions must demonstrate ambient progress. Such demonstrations have typically been made through mathematical dispersion modeling which predicts the ambient impact of various emissions.

This Document authorizes use of a three-tiered screen with the degree of required modeling linked to the likely ambient impact of the proposed trade. The following sections describe use of this modeling screen to approve many trades without full-scale ambient modeling. Use of this modeling screen to define the scope of generic rules is discussed in Section II below.

(i) *Level I:* In general no modeling is needed if the proposed TSP, SO_2 or CO trade does not result in a net increase in applicable baseline emissions, the relevant emission sources are located in the same immediate vicinity, and no increase in emissions occurs at the source with the lower effective plume height. In such cases it can reasonably be assumed that "pound-for-pound" trades will produce ambient effects equivalent to what current modeling would predict, and modeling is not required.

(ii) *Level II:* Only limited modeling involving the specific emission sources in the trade is needed for trades not included in Level I, if there is no net increase in applicable baseline emissions and if emissions after the trade will not cause a significant air quality impact at the receptor of maximum predicted impact. In determining "significant" impact, states may use the significance levels established by EPA for determining when air quality monitoring is necessary for PSD cases: 10 $\mu g/m^3$ for the 24-hour standard for TSP; 13 $\mu g/m^3$ (24-hr) for SO_2; and 575 $\mu g/m^3$ (8-hr) for CO. (*See,* 45 FR 52709, Aug. 7, 1980). These levels appropriately identify trades whose potential ambient impact need not be further evaluated before approval.

(iii) *Level III:* Full dispersion modeling, considering all sources in the area of impact, is required if net applicable baseline emissions will increase as a result of the trade *or* if the trade will have a significant impact on air quality at the receptor showing maximum ambient impact.

This modeling screen will ensure that the air quality impact of trades is equivalent to the impact of the original SIP limits.

c. *Trades Should Not Increase Net Baseline Emissions in Nonattainment Areas.* Congress required *nonattainment areas* to demonstrate reasonable further progress (RFP) by reducing emissions each year in amounts sufficient to attain ambient standards by statutory deadlines. In general, RFP is measured by an areawide quantity of reduced emissions.

Trades in such areas which increase total emissions can generally occur only as individual SIP revisions in which the state either demonstrates that the trade is consistent with RFP or revises RFP as part of the proposed SIP revision. EPA will approve such revisions as amendments to the SIP, provided they comport with ambient air quality standards and reasonable further progress.

However, such trades may occur under generic rules where existing sources were required to reduce emissions beyond the amount required to bring the area into attainment. In such cases a growth margin was created which may be used at the discretion of the state to compensate for any increases in emissions without violating reasonable further progress requirements.

In attainment areas trades increasing total emissions could generally be permitted, but may consume some or all of the increment, trigger PSD review, or both.

d. *Emissions Trades Should Not Increase Hazardous Pollutants.* Under the Clean Air Act all sources must meet applicable Section 112 (NESHAPs) regulations for hazardous air pollutants. Except as may be specifically permitted in future Section 112 regulations, a source may neither use a bubble to meet these requirements, nor increase emissions beyond the levels they prescribe.

Where pollutants have been listed under Section 112, but are not yet subject to specific regulations, states may allow trades consisting of equivalent increases and decreases of the same listed pollutant at reasonably close emission points. States may also approve trades in which reductions in hazardous emissions compensate for increases in non-hazardous emissions. For example, a source may trade benzene for any non-hazardous VOC, if the benzene emissions are decreased (i.e., "traded down").

e. *Emissions Trades Cannot Be Used to Meet Technology-Based Requirements.* The Clean Air Act specifically requires new or expanding sources to meet technology-based new source performance standards (NSPS), regardless of the attainment status of the area in which they are located. This requirement prohibits use of bubbles to meet or avoid NSPS, and has been interpreted to bar use of such a bubble to meet new source review requirements for best available control technology (BACT) in PSD areas, or lowest achievable emission rate control technology (LAER) in nonattainment areas. Thus, new emissions sources subject to new source review cannot use ERCs from existing sources to satisfy these requirements.

Expanding or modernizing sources can, however, use *internal* emission reductions from within the same plant to "net out" of new source review. Such sources still must meet NSPS, but are not subject to BACT in attainment areas (45 FR 52676; Aug. 7, 1980) or LAER in nonattainment areas (46 FR 50766; Oct. 14, 1981), since they are not considered new sources under Parts C and D of the Clean Air Act.

f. *Trades Involving Open Dust Emissions.* Trades involving open dust sources of particulate emissions may be approved based on modelled demonstrations of ambient equivalence. Sources proposing such trades should be required to undertake a post-approval monitoring program to evaluate the impact of their control efforts. If the results of monitoring indicate that initial open dust controls do not produce the predicted air quality impact, further enforceable reductions may be required. States must either require sources to acknowledge their responsibility for further reductions, or deem trading applications to be such an acknowledgment, as a condition of approval.

2. *Procedural Steps for Using ERCS.* Emission trades may be implemented through individual SIP revisions or state generic rules. This section describes principles applicable to either procedure. General principles for generic rules are discussed in Section II below. Special considerations for trades which still require individual SIP revisions are discussed in Section III.

a. *Bubbles Can Be Used to Achieve Compliance.* The bubble policy required that sources be subject to binding compliance schedules based on original SIP emission limits before being eligible to apply for bubbles. This requirement threatened sources with tight milestones for the purchase of conventional control equipment and tended to discourage both rapid compliance and flexibility. Under today's Policy Statement states may promote rapid compliance by allowing sources to agree to emission limits established as part of their bubble application, instead of requiring sources to agree to compliance plans based on their original SIP limits before an application can be filed.

b. *Extensions of Compliance Deadlines.* States may extend compliance deadlines for VOC or CO sources on a case-by-case basis as part of bubble approvals. The Clean Air Act limits such extensions to sources which are located in areas that have received VOC or CO attainment extensions until 1987, and whose bubble will be consistent with reasonable further progress requirements. Because this will usually require a revision of the state's reasonable further progress demonstration, such extensions must generally be submitted as SIP revisions.

However, states may also grant compliance extensions without case-by-case SIP revisions as part of bubble approvals under a generic rule. The rule should provide that: (1) Extensions may only be granted in areas which have received attainment extensions to 1987; and (2) the total amount of reductions claimed in the state's approved RFP demonstration will not be reduced for each year in question. For example, if a source wishes to defer 100 tons per year of reductions from 1982 to 1985, then as part of the bubble approval, the state must show that an additional 100 tons per year of reductions has already occurred in 1982, or that provisions for such additional reductions already exist.

c. *Pending Enforcement Actions.* A bubble cannot be approved for an individual emission source which is presently the subject of a federal enforcement action or outstanding enforcement order unless EPA (and where necessary the appropriate court) approves the proposal and the compliance schedule it contains. This applies to civil actions filed under Clean Air Act Section 113(b), criminal actions filed under Section 113(c), a notice imposing noncompliance penalties issued under Section 120, administrative orders issued under Section 113(a), or a citizen suit filed under Section 304 where EPA has intervened.

This requirement need not preclude bubble approvals under generic rules, provided an appropriate mechanism for securing and recording EPA approval is used. Sources should, however, be aware that such approvals cannot be finally effective until approved by the appropriate court.

C. Banking Emission Reduction Credits

State SIP rules may include a banking provision which addresses ownership and holding of ERCs over time. Without such a provision, firms risk losing surplus reductions should a major SIP revision or new set of control requirements be instituted. Generic banking rules can afford such ERCs substantial protection consistent with the Act's mandate to attain and maintain ambient standards.

The bank can accept and evaluate requests to certify an ERC, serve as a clearinghouse for credits on deposit, and account for transfers and withdrawals of ERCs. These roles will generally be performed by the state as part of its normal permitting activities.

The following sections address both minimum legal requirements for state banking rules and issues states should consider. States may adopt other approaches which produce equivalent results.

1. *Banking Rules Must Designate an Administering Agency.* Banking rules must identify the entity responsible for specific functions. While the state will ordinarily be responsbile for verifying and processing ERC requests, all or part of this responsibility may be delegated to other organizations. Such organization(s) must possess the resources and legal authority to implement delegated activities.

2. *Only ERCs May be Banked.* Banked emission reductions msut be *surplus, permanent, quantifiable* and *enforceable.* This generally means that such reductions must be made at the time they are deposited in the bank as ERCs. *However,* if a firm commits to produce a specific reduction in the future, a state may allow a conditional deposit to be made. In all cases the reduction must actually be achieved before it can be used in an emissions trade.

3. *Procedures for Banking ERCs Should be Defined.* To speed approval of trades and provide greater cerainty for potential ERC creators and users, state banking rules should clearly identify which proposed emission reductions can qualify to be credited and banked, the information required of sources to substantiate their claim for credit, and any required application forms.

4. *Banking Rules Must Establish Ownership Rights.* To prevent two entities from claiming the same ERCs, state banking rules must specify who can own ERCs. For example, while the source creating the ERC will generally be its owner, the state could, as part of its rule, reserve ownership of certain classes of ERCs to itself or local governments.

5. *Banking Rules Must Establish an ERC Registry or Its Equivalent.* An ERC registry or equivalent instrument lets states track ownership, use, and transfer of all banked ERCs. Banking rules must provide that no transfer of title to a banked ERC will take effect until the transaction is reflected in the registry. This tracking system is important to minimize disputes over ownership and provide a central list of certified ERCs which may be available. It can also provide useful information for quickly evaluating any proposed use of a banked ERC.

Information which may help evaluate proposed use of a banked ERC should be recorded at the time of its creation and entered as part of its banking record. This information should include the location of the source creating the ERCs, its stack parameters, the temperature and velocity of its plume, particle size, the existence of any hazardous pollutants, daily and seasonal emission rates, and any other data which might reasonably be necessary to evaluate future use.

To perform these tracking and clearinghouse functions the ERC registry must be accessible to the public. Subject to confidentiality considerations, states should make copies of the ERC registry available at convenient locations and times, and may want to publish a periodic summary of banked ERCs.

6. *Possible Adjustments to ERCs Based on Enforcement Considerations.* To avoid legal problems, banking rules should clearly state what, if any, changes may occur to ERCs after they have been banked. Once an ERC has been used by another source to meet a permit requirement, any violation of the conditions under which that ERC was created should result in enforcement against the source *producing* that emission reduction and not the source *using* the ERCs. If a state attempted to enforce against the source using purchased ERCs, a complex set of third-party lawsuits would ensue. This would likely discourage sources from purchasing ERCs in the Future.

7. *Possible Adjustments to ERCs Based on Ambient Attainment Considerations.* To assure the validity of its demonstration(s) of attainment, a state with a banking rule should assume that all banked emissions will ultimately be used. Thus, in evaluating their ability to attain national standards, states should add to their inventory or measured ambient value, all unused banked reductions at the site at which they were created.

Additional emission reductions may be required from sources because of their area's failure to attain ambient standards, because of an increment violation, or because new RACT requirements are being imposed under a SIP schedule. The existence of banked ERCs must not interfere with states' ability to obtain these additional reductions. For this reason state banking rules should specifically address how ERCs will be treated if additional reductions are required. Available options include:

a. *ERCs Are Absolutely Guaranteed Against Adjustment.* The state would determine the required quantity of reductions and assess necessary controls on the inventory. Sources with banked ERCs would not be exempt from any requirement for additional reductions, but could satisfy that requirement by using their banked ERCs, by reducing emissions elsewhere, or by purchasing equivalent ERCs.

To effectively implement this option, it would be particularly important to state new control requirements in terms of "RACT-equivalent" reductions.

b. *Current ERCs Are Fully Preserved,* but either their use *or* future ERC deposits are suspended until the SIP has committed to secure reductions sufficient to reestablish reasonable further progress or cure an increment violation. Use of either type moratorium would be consistent with air quality objectives while allowing sources to retain or use their entire quantity of banked ERCs. However, this option may be undesirable because of uncertainty regarding the moratorium's start, duration, or potential interference with user planning.

c. *Across-the-Board Discounting.* Under this option, all ERCs in the bank would be discounted by the same factor. For example, if a 10% additional reduction is required from a category of sources for the SIP's new demonstration of attainment, the state would discount all banked ERCs from those types of sources by 10%. Although the quantity of ERCs held by a firm will be reduced, the overall supply of ERCs will decrease, while demand will increase. Therefore, the overall value of remaining ERCs is likely, at minimum, to remain the same. Indeed, other sources may purchase banked ERCs to meet the 10% reductions required of them.

This option is relatively straightforward for VOC or NO_x. For SO_2 or TSP more detailed, source-specific modeling would generally be required to allocate the discount necessary to demonstrate attainment.

States may adopt any of these methods of accommodating possible additional reductions. They may also adopt any equivalent method which achieves the same objectives.

II. Trades Covered by State Generic Rules

This section explains expanded opportunities for states to develop generic rules under which certain classes of emissions trades will be exempt from individual SIP revision.

A. General Principles for Evaluating Generic Rules

A generic rule is approvable if it assures that (1) applicable net baseline emissions will not increase; (2) emissions trades otherwise requiring SIP revisions under §§ 110(i) and 110(a)(3) of the Clean Air Act will be evaluated under procedures that are sufficiently replicable in operation; and (3) emission limits produced under the rule will not interfere with ambient attainment and maintenance. Replicability generally means that specific modeling procedures are prescribed and that states have appropriately defined their choice of models, model inputs, and modeling techniques in applying these procedures to specific trades. Thus, these trades should not create new ambient violations or interfere with the planned removal of existing violations. By approving such generic rules EPA approves in advance an array of acceptable SIP emission limits, and no further case-by-case EPA approval is required.[4]

B. Scope of Generic Rules

States may use a range of mechanisms to exempt trades from EPA review as individual SIP revisions. While several mechanisms are explained below, states may submit other generic rules that satisfy these basic principles.

1. *De Minimis Trades.* Trades in which net baseline emissions do not increase and in which the sum of the emission increases, looking only at the increasing sources, totals less than 100 tons per year after applicable control requirements, may proceed without a

---

[4] Replicability more generally means a high likelihood that two decision-makers applying the rule to a given trade would reach the same conclusion. For one example of a generic rule incorporating a very simple formula that meets the test of replicability, see 46 FR 20551 (Apr. 6, 1981).

SIP revision. Such trades will have at most a *de minimis* impact on local air quality because only minor quantities of emissions are involved. Moreover, because only trades which produce no net increase in emissions can be exempt, overall air quality will not suffer. The Federal resources required to evaluate these trades could best be used to evaluate actions that have a potential impact on air Quality.[7]

2. *VOC or NO_x* Trades. All VOC or NO_x trades under a generic rule that assures no net increase in applicable baseline emissions may occur without individual SIP revisions.

The ambient impacts of VOC and NO_x emissions are area-wide rather than source-specific. All such emissions within a broad area are considered comparable, regardless of plume height, topography or related factors. Thus, the ambient impact of trades involving VOC or NO_x will by definition be equivalent to that of the sum of the SIP emission limits for the emission sources involved in the trade. As long as the sum of these emission limits is not exceeded, the limits for each specific emission source can be reallocated without adversely affecting air quality. This essentially arithmetical task is so mechanical that VOC or NO_x trades developed in this manner cannot reasonably interfere with ambient attainment and maintenance.

3. *SO_x* CO, or TSP Trades. For trades involving SO_x CO, or TSP it is more difficult, but by no means impractical, to develop a generic rule which assures that valid ERC uses cannot reasonably interfere with attainment and maintenance.

The ambient impact of these pollutants depends on site-specific factors such as topography and plume height which are ordinarily evaluated by ambient modeling. However, if the emission sources are located in the same immediate vicinity and emissions decrease at the source with the lower effective plume height, therefore minimizing localized ambient impact, equal increases and decreases in emissions from these sources will ordinarily produce equivalent ambient effects (See Level I of the Modeling Screen). As a result, trades involving emission sources within Level I may be treated in the same manner as trades involving VOC or NO_x and may be exempted from individual SIP revisions.

EPA will normally approve generic rules that define "same immediate vicinity" as up to 250 meters between the individual emission sources involved in a trade. *However*, where such trades involve areas with complex terrain, some modeling might still be required to assure that ambient impact is properly considered. Generic rules should specify criteria for identifying such circumstances and for defining what modeling will be required.

4. *Other Mechanisms for Exempting TSP, SO_x, or CO Trades from Individual SIP Revisions.* Other TSP, SO_x or CO trades can be exempted from individual SIP revisions if they occur under state generic rules which satisfy the replicability and air quality requirements stated above.

Possible generic approaches include:

(a) Developing SIP rules which allow identified sources to meet an array of specific emission limits consistent with ambient attainment and maintenance. For example, states could approve a modeled formula for two or more specific emisson sources which would both satisfy ambient concerns and let firms determine particular permit limits at each emission source. This formula would have to be adopted as part of the SIP.[8]

(b) Developing criteria for use of simplified Level II modeling (see section I.B.1.b, above) for specified trades. This approach would exempt trades which (1) produce no net increase in applicable baseline emissions, (2) can routinely be modeled in a predescribed manner, and (3) will not have significant ambient impact. The generic rule must specify either the particular model that will be employed in a given stituation, or criteria for selecting models in specified circumstances. To limit variability in modeling results the rule must also specify procedures for selecting input data (e.g., wind speed, stability class, source emission rate) which are sufficiently definite to meet the test of replicability. To determine whether a trade will have significant ambient impact these procedures should assess whether the change in emissions after the trade from the increasing source has the potential to cause an increase of more than 10 $\mu g/m^3$ over at 24-hour period for TSP, 13 $\mu g/m^3$ (24 hours) for SO_x, or 575 $\mu g/m^3$ (8 hours) for CO at the receptor of maximum predicted impact.

C Applicability of Generic Rules To Process Fugitive and Open Dust Emissions Trades

Trade involving *process fugitive emissions of VOC or NO_x* may routinely be approved under generic rules. However, because of their dispersion characteristics, it is more difficult to define generic rules that can be applied in a sufficiently replicable fashion to trades involving process fugitive or open dust TSP emissions.

In general *TSP trades involving process fugitive emissions* can be approved under generic rules if: (1) process fugitive emissions are traded against similar sources of process fugitive emissions, or (2) emissions from point sources are traded against process fugitive emissions which can reasonably be represented by a point-source dispersion pattern. This means that relevant parameters such as emission release height must be readily determinable. Unless such trades fall within Level I of the modeling screen or are *de minimis*, only processes whose fugitive emissions can be adequately represented by the dispersion model(s) specified in an approved generic rule can be included in a trade under that rule.

For *TSP trades involving open dust emissions* states should be aware that approvable generic rules which appropriately limit the choice of screening models and relevant inputs (including acceptable emission factors) will currently be difficult to formulate. Accordingly, open dust trades generally will have to be submitted as individual SIP revisions.

D. Enforcing Emission Limits Under Generic Rules

Alternative emission limits approved under generic rules are considered by EPA to be federally enforceable. Generic rules should specify that such alternative limits become applicable requirements of the SIP for purposes of §§ 113 and 304 of the Clean Air Act and are enforceable in the same manner as other SIP requirements. To assure that EPA and citizens know what emission limits apply, generic rules should also specify that EPA be informed of applicable emission limits before and after the trade, following approval of the trade by the state.

E. EPA Oversight of Trades of Under Generic Rules

The Clean Air Act requires EPA to monitor administration of SIPs, including generic rules. *See* § 110(a)(2)(H). EPA will audit the information supplied for each trade and may request additional relevant information. Should EPA determine that approved trades are substantially inconsistent with generic rules in the SIP, it will notify the state and specify any necessary remedial measures.[9]

---

[7] Although states may exempt *de minimis* trades from federal SIP revisions, these trades are still subject to ambient tests. They should accordingly be evaluated by the state under the modeling screen (See Section I.B.1.b. above) or an equivalent approach.

[8] For example, the emission limits for the four stacks at the stuart Power Plant in Adams County, Ohio are 3.16 pounds of SO_2 per million BTU at each stack, or at the plant's choice (after notification to EPA), any limit in pounds per BTU which satisfies the following equation: 0.0791 ($EL_1 + EL_2 + EL_3 + EL_4 < 1$. See 40 CFR 5.1881(11).

F. Public Comment

For trades occuring under generic rules, existing state statutes or regulations will generally provide reasonably adequate notice and comment opportunities. If these opportunities are not provided generic rules should explicitly address this issue.

To ensure public awareness consistent with § 304 of the Clean Air Act, states should also, at a minimum, publish any changes to emission limits which result from trades approved under a generic rule (see 46 FR 20554; April 6, 1981).

III. Trades Not Covered by State Generic Rules

In the absence of a generic rule, states and sources may continue to use SIP revisions to effect bubble or external offset trades. Individual trades may also fall outside the scope of an approved generic rule and still be implemented as individual SIP revisions. The principles described in the Policy Statement and this Document will generally be used to evaluate these emission trades.

Because of the ability of the SIP revision process to take account of individual variations, many trades which could not be accomplished under a generic rule may be acceptable use individual SIP revisions. For example, proposed bubles which produce a net increase in baseline emissions could nevertheless be approved through a SIP revision showing that requirements for attainment and maintenance were satisfied. In submitting such a bubble application, the state would have to revise its reasonable further progress demonstration to account for the increase in emissions and EPA would review the proposal to determine if the demonstration of attainment and RFP were satisfactor. Without such a SIP revision, trades increasing net baseline emissions would generally be acceptable only if compensating additional controls were already required in the SIP.

Through the SIP revision process, states and sources may also demonstrate that a general principle discussed in Section I above does not apply to their particular circumstances, or that such a principle may be satisfied in other ways. For example, they may show that a RACT baseline is unnecessary for a particular source because resulting reductions are not needed for attainment; that despite general requirements for use of an actual emissions baseline, an allowable baseline is acceptable in a particular situation based on air quality modeling; or that reductions from specific shutdowns or uninventoried sources can be fully credited without interfering with reasonable further progress and attainment.

EPA will make reasonable efforts to take prompt action on SIP trading proposals after a state has ruled on an individual application and submitted it to the Agency. EPA will encourage "parallel processing" of proposals, with EPA and state officials conducting concurrent review so that both agencies can give public notice of proposed action at roughly the same time. EPA can then take prompt final action after the state completes its proceedings, provided the state does not substantially alter the proposal after public notice. EPA will also publish non-controversial SIP revisions as immediate final actions, converting them to proposals only if adverse comments are received within 30 days (see generally 46 FR 44477; Sept. 4, 1981).

Appendix.—Regional EPA Emissions Trading Coordinators

Region I: Marcia Spink, Stationary Source Section, Air Programs Branch, John F. Kennedy Federal Building, Boston, Massachusetts 02203, (617) 223–4448; FTS 223–4448

Region II: Linda Comerci, Permits Administration Branch, Planning and Management Division, 26 Federal Plaza, New York, New York 10007, (212) 264–4333; FTS 264–4333

Region III: David Arnold, Air Programs Branch, 6th and Walnut Streets, Philadelphia, Pennsylvania 19102, (215) 597–7936; FTS 597–7936

Region IV: Archie Lee, Air Programs Branch, 345 Courtland Street, N.E., Atlanta, Georgia 30308, (404) 257–3286; FTS 257–3286

Region V: Dick Dalton, Mary Ryan, Air Programs Branch, 230 South Dearborn Street, Chicago, Illinois 60604, (312) 886–6063; FTS 886–6063

Region VI: Michael Mendias, Air Programs Branch, First International Building, 1201 Elm Street, Dallas, Texas 75270, (214) 767–2734; FTS 729–2734

Region VII: Charles Whitmore, Air Support Branch, 324 East 11th Street, Kansas City, Missouri 64106, (816) 374–6525; FTS 758–6525

Region VIII: Dale Wells, Air Programs Branch, 1860 Lincoln Street, Denver, Colorado 80295, (303) 837–3763; FTS 327–3763

Region IX: Wally Woo, Air and Hazardous Materials Section, 215 Freemont Street, San Francisco, California 94105, (415) 974–8210; FTS 454–8210

Region X: Dave Bray, Air Programs Branch, 1200 6th Avenue, Seattle, Washington 98101, (206) 442–1352; FTS 399–1352

[FR Doc. [illegible] Filed 4-6-82; [illegible]]

BILLING CODE [illegible]

---

[9] A trade which does not meet the requirements of a generic SIP rule is not part of an SIP and by defintion cannot replace prior value emission limits in the SIP. (See 46 FR 20554–8; April 6, 1981). In these cases EPA must reserve the right to take remedial action to assure attainment and maintenance, including as a last resort enforcement of the original SIP limits.

NSF/PRA-82013

S-82 10143

EMISSIONS TRADING:
AN OVERVIEW OF THE EPA POLICY STATEMENT

by
Gordon L. Brady
Richard E. Morrison

Prepared for:

NATIONAL SCIENCE FOUNDATION
Directorate for Scientific, Technological, and International Affairs
Division of Policy and Research Analysis

Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the National Science Foundation.

PRA Research Report 82-2
May 1982

ABSTRACT

In this paper the authors examine the Emissions Trading Statement, announced by the Environmental Protection Agency in the spring of 1982 as a major regulatory reform initiative of the Reagan Administration. The Statement consolidates in a common currency, called the Emission Reduction Credit (ERC), the emission reductions achieved and used through current administrative procedures for the bubble, netting, offset, and banking programs. The Statement provides guidelines for air quality management regions to develop generic State Implementation Plan (SIP) provisions governing transactions in ERCs. Transactions that meet conditions specified in the generic rules have pre-approved federal status; other transactions must be federally approved as SIP revisions.

The Statement amounts to an invitation to firms to create "surplus" discharge reductions beyond current control requirements specified by applicable SIPs or uniform technology standards. The incentive for participation is the opportunity to make a profit by selling (or by banking for future sale) ERCs to other firms that face higher marginal emissions control costs. The "payoff" for the region is the nominal achievement of least cost regional solutions for given total limitations on permissible units of pollutant discharges.

The existing regulatory implementation incentive structure for stationary source dischargers is described in Section 1 of this paper. The Statement's evolution as a logical extension of administrative procedures already in limited use is discussed in Section 2. Policy issues that may limit the cost-effectiveness of the proposed changes in the current regulatory implementation incentive structure are discussed in Section 3. The authors' summary of findings and concluding observations are presented in Section 4.

EMISSIONS TRADING: AN OVERVIEW OF THE EPA POLICY STATEMENT

by
Gordon L. Brady*
Richard E. Morrison*

1.0 INTRODUCTION

The Emissions Trading Policy Statement,[1] announced by Environmental Protection Agency (EPA) Administrator Anne Gorsuch on April 2, 1982, is the first major regulatory reform effort by the EPA under the Reagan Administration. The Statement effectively amounts to an invitation for firms to reduce discharges beyond current requirements specified in their State Implementation Plan (SIP) or in applicable uniform technology standards, the incentive for participation being the opportunity to make a profit by selling discharge permits to firms that face higher marginal costs of control.

The Statement is a transitional air quality management strategy in that it extends and modifies the existing regulatory implementation incentive system based on uniform technology standards. Although it has been called a major regulatory reform effort by EPA to increase regulatory flexibility and the cost-effectiveness of the existing air quality management program, it does not represent the major departure from current policies that would be required by commitment to a full-fledged marketable permit system. Rather, it is largely a cosmetic expansion and consolidation of other regulatory reform efforts already in use. It is a set of administrative regulations that encompasses in a single framework other administrative reforms that have been in use for some time, including the bubble, netting, and offset procedures, and a system of banking or storing permits for later use or sale. The Statement takes these four transactional mechanisms, much as they are now, and consolidates them in a single, more readily usable system based on the legal entity called an "Emission Reduction Credit" (ERC).

The ERC serves as the "currency" or medium of exchange in the development of an emission trading system by the air quality management region.[2] Transactions involving the creation, use, and banking of ERCs are subject to various administrative restrictions imposed through "generic" SIP provisions and case-by-case determinations as SIP revisions. The Statement is a set of guidelines for the development of the generic rules, defined as sufficiently "mechanical in operation and sufficiently replicable to produce emission limits which will not interfere with attainment and maintenance of ambient standards."[3]

---

*The authors are, respectively, a private consultant (formerly Director of Economic Analysis for the National Commission on Air Quality), and Senior Policy Analyst, National Science Foundation. They acknowledge the helpful review comments and suggestions of Edward H. Clarke of the Office of Management and Budget, Charles W. Bausell, Jr. of the General Accounting Office, and John P. Palmisano of the EPA Regulatory Reform Staff.

In section 1 of this paper, the existing regulatory implementation incentive system, based on uniform technology standards, is described. In Section 2, the Statement is presented as a logical extension of the existing system. Section 3, which we refer to as "Policy Issues in the Emissions Trading Policy Statement," is a discussion of those factors in the Statement that will limit the cost-effectiveness of the proposed changes in the regulatory implementation structure. Concluding comments are provided in Section 4.

1.1 The Existing Regulatory System

The primary unit in air quality management is a point source or combination of point sources that generates residuals. All air quality management strategies must ultimately affect the behavior of dischargers at the level of the source (e.g., an industrial plant, farm, mining operation, management unit of a national forest, household, or motor vehicle). A residual is a nonutilizable output -- material or energy -- to a specific source. For that specific source the residual has zero value or a value less than the cost of its recovery and transport for use in the same source or another source. A gaseous, liquid, or solid residual may or may not be a pollutant regulated under the Clean Air Act.

Sources generate residuals that have different physical and chemical relationships. Some physical and chemical reactions form the pollutants for which permissible concentrations in the ambient air have been estimated and established as the National Ambient Air Quality Standards (NAAQS). (See Exhibit 1.) The driving force behind air quality management in the U.S. is the attainment of the NAAQS.

Primary and secondary NAAQS have been set for each of seven criteria pollutants. Primary NAAQS are designed to protect public health. Secondary standards, which impose additional requirements, are designed to protect the public welfare from adverse effects, both known and anticipated. The functional meaning of having separate primary and secondary NAAQS may best be described as that of a target and goal relationship, i.e., the primary NAAQS serve as targets and the secondary NAAQS as goals. The Clean Air Act calls for attaining the primary standard "as expeditiously as practicable" (but in no case is attainment required in less than three years from the date of approval of the SIP) while specifying a reasonable time at which such secondary standard will be attained.[4]

The regulatory approach mandated by the Clean Air Act requires stationary source dischargers to adopt state-of-the-art residuals management technology and to meet uniform technology standards. The uniform technology standards, in descending order of stringency as required by statute, are Lowest Achievable Emission Rate (LAER) and Best Available Control Technology (BACT).[5] Reasonably Available Control Technology (RACT) is determined by states based on Control Technique Guideline documents prepared by EPA.

Uniform technology standards are based on what technology can accomplish, rather than on what is required to attain a specific ambient air quality standard in a specific air quality management region. In this sense, the uniform technology standards make no direct correlation between source discharges and the necessary measures for attainment of the health-based ambient air quality standards. Consequently, the use of uniform technology standards may cause a region to exceed or fall short of the ambient air quality standards.

The set of permissible implementation incentive options also varies according to attainment status. The offset and bubble are market-based approaches that evolved as administrative responses to the recognition of implementation incentive problems.* Progress in the attainment of NAAQS was slow and costly; often there were political pressures in favor of growth in nonattainment regions.

The "bubble" refers to administrative regulations that allow a firm to propose an alternative emission strategy to that provided in the SIP. All point sources involved in the transaction are treated as a single entity, although a single permit may not be used. The bubble concept must be distinguished from the administrative procedures that are used to implement the bubble. The bubble concept is used to describe any attempt in residuals management to place an imaginary bubble over the multiple point sources and to treat the source administratively as a single unit process subject to a maximum discharge limitation. On the other hand, the bubble policy is the set of administrative procedures that allow point sources to increase discharges beyond currently applicable uniform technology standards or permit conditions if a greater or compensating reduction in discharge is accomplished at another point source within the same plant or in other plants owned by the same firm. In this sense, the bubble procedure allows "intrafirm trades" in discharge reductions. In order to be eligible to use the bubble procedures, a source must be in compliance with SIP requirements or have agreed to a compliance schedule based on its original SIP limitations. An activity may not use the bubble procedures to achieve compliance.[6] Only PSD regions and nonattainment regions that demonstrate attainment by the statutory deadline of December 1982 may allow sources to use bubble procedures.[7]

Netting, based on the bubble concept, allows sources that undergo major modifications to avoid review as a new source. It is a procedure that allows an existing source that undergoes major modification to be exempted from (1) new source review procedures for all new sources; (2) LAER determination in nonattainment regions; (3) BACT determination in PSD regions; (4) offset requirements; or (5) a construction ban. In effect, netting extends to major modifications the bubble procedures that apply to existing sources.

The offset policy is a set of administrative procedures that apply the bubble concept to allow "interfirm" trading of emission permits. Conceptually, the offset and bubble procedures are similar. However, differences occur in their application. In their current form, the offset procedures are allowed in both nonattainment regions and PSD regions and for both existing and new sources. Bubbles, on the other hand, apply only to existing sources and are not allowed in regions that do not demonstrate attainment by 1982. Offsets require discharge reductions from existing sources that exceed the discharges from the new source, in order to produce a net improvement in ambient air quality, whereas bubbles require equivalent ambient effects.

---

*As will become clear in the discussion that follows, the offset strategy, which was the first market-oriented alternative to command and control approaches introduced administratively by EPA, is actually a variant of the bubble concept, which was not introduced administratively until some time later. For the purpose of describing the conceptual evolution of EPA market-oriented strategies, we start here with the bubble and then extend the bubble concept to transactions between different firms, i.e., the offset strategy.

EXHIBIT 1

NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS)

Pollutant	Averaging time	Primary standard levels	Secondary standard levels
Particulate matter	Annual (geometric mean)	75ug/m^3	60 ug/m^3
	24 hrs [b]	260 ug/m^3	150 ug/m^3
Sulfur oxides	Annual (arithmetic mean)	80 ug/m^3 (0.03 ppm)	--
	24 hrs[b]	365 ug/m^3 (0.14 ppm)	--
	3 hrs[b]	--	1300 ug/m^3 (0.5 ppm)
Carbon monoxides	8 hrs[b]	10 ug/m^3 (9 ppm)	10 ug/m^3 (9 ppm)
	1 hr[b]	40 ug/m^3* (35 ppm)	40 ug/m^3* (35 ppm)
Nitrogen dioxide	Annual (arithmetic mean)	100 ug/m^3 (0.05 ppm)	100 ug/m^3 (0.05 ppm)
Ozone	1 hr[b]	240 ug/m^3 (0.12 ppm)	240 ug/m^3 (0.12 ppm)
Hydrocarbons (nonmethane)[a]	3 hrs (6 to 9 a.m.)	160 ug/m^3 (0.24 ppm)	160 ug/m^3 (0.24 ppm)
Lead	3 mos	1.5 ug/m^3	1.5 ug/m^3

*EPA has proposed a reduction of the standard to 25 ppm (29 ug/m^3).
[a] A nonhealth-related standard used as a guide for ozone control.
[b] Not to be exceeded more than once a year.

SOURCE: Reprinted from CEQ (1980), p. 172.
Information provided by the U.S.
Environmental Protection Agency

1.2 Current Regulatory Implementation Incentive System

Exhibit 2 describes the current national regulatory implementation incentive system in use in the U.S. It shows regulatory requirements and implementation options for existing activities and new or modified activities in nonattainment regions and PSD regions.

EXHIBIT 2

CURRENT NATIONAL REGULATORY IMPLEMENTATION INCENTIVE SYSTEM

	EXISTING SOURCES	NEW SOURCES AND MAJOR MODIFICATIONS
PSD REGIONS		
o At ceiling of PSD increment or primary standard	Bubble allowed Control levels determined by state Offsets allowed	Offsets allowed BACT and NSPS required (must show no violation of increment) Netting allowed to avoid review as a new source with possible BACT determination
o Regions with some or all of the PSD increment remaining	PSD program required, but no formal SIP	Subject to the same requirements as above, with PSD program required but without a requirement for a formal SIP
NONATTAINMENT REGIONS		
o SIP demonstrates attainment by 1982 (or has conditionally approved SIP)	Bubble allowed Offsets allowed RACT may exist as a control requirement for some activities in SIPs that failed to demonstrate attainment on initial submittal	NSPS required if NSPS regulations apply LAER required Offsets required Netting allowed to avoid review as a new source with possible LAER determination
o SIP not demonstrating attainment by 1982	Bubble not allowed RACT required Margin of growth required by use of offsets or an accommodative SIP	Same as above
o SIP not demonstrating attainment by 1987, or region without approved SIP that demonstrates attainment	Same as above	Same as above

A region with ambient air quality concentrations of a regulated pollutant less than the pollutant's NAAQS is said to have achieved attainment and is classified as a "Prevention of Significant Deterioration" (PSD) region with respect to that pollutant. For administrative purposes, PSD regions are divided into two categories: those that are at the ceiling of the PSD increment (allowable unit of air quality consumption) or at or near the primary NAAQS, and those with some (or all) of the PSD increment remaining and available for air quality management strategies.

Depending on the SIP, existing sources in PSD regions that are at the ceiling of the PSD increment or primary standard may use the bubble procedures and offset transactions. The control levels are determined by the air quality management region with the federal role limited. New sources or major modifications to existing sources are allowed to undertake bubble and offset transactions for existing point sources. For new sources, the installation of BACT and NSPS is required. As in nonattainment regions, netting is allowed to avoid LAER determination or a construction ban on the siting of new sources.

PSD regions with some or all of the PSD increment remaining are required to have a PSD program, but no formal SIP. However, the PSD program serves the same role that is served by the SIP in other categories of attainment. The PSD program represents a set of administrative procedures for siting new growth and protection of PSD increments. It may include a provision for bubble and offsetting. The PSD program may be administered by EPA or assigned to the air quality management region.

An air quality management region that is not a PSD region with respect to a regulated pollutant is called a nonattainment region with respect to that pollutant. For administrative purposes, nonattainment regions may be divided into three categories:

- those regions with SIPs that demonstrate attainment by 1982;
- those regions with SIPs that do not demonstrate attainment by 1982; and
- those regions with SIPs that do not demonstrate attainment by 1987 or those regions without an approved SIP that demonstrates attainment.

The stringency of uniform technology standards and the availability of the bubble and offset policies differ for existing sources or major modifications to existing sources. In regions with SIPs that demonstrate attainment by 1982, the bubble and offset policies are allowed but not required for existing sources. That is, for existing sources the air quality management region has the choice of whether to make such policies part of its SIP. In order to attain the the NAAQS, RACT may be required for some sources. As a matter of national policy, RACT for specific sources is required only to the extent that the air quality management region does not meet the NAAQS.

Administratively the treatment is identical for regions with SIPs that do not demonstrate attainment by 1982 and for regions that do not demonstrate attainment by 1987 or do not have approved SIPs that demonstrate attainment. The bubble is not allowed, RACT is required for all dischargers of the nonattainment pollutant, and a margin for growth is required by use of offsets or an "accommodative SIP," an administrative approach allowing abatement efforts to focus on a few sources without requiring comparable levels of abatement by other sources.

New sources or major modifications to existing sources in nonattainment regions are subject to more stringent control requirements than are existing sources. In nonattainment regions that demonstrate attainment by 1982, new sources and major modifications to existing sources are required to install LAER and use the offset procedures. They may use netting procedures to avoid new source review for LAER determination and the imposition of a construction ban. Regions with SIPs that do not demonstrate attainment by 1982 or 1987 or do not have an approved SIP are subject to the same requirements.

A region may be in compliance with the NAAQS for one pollutant (and therefore be classified as PSD) but out of compliance with requirements for another pollutant (and therefore, be classified as nonattainment). Consequently, under the Clean Air Act a new source can be subject not only to NSPS but also to either BACT or LAER or both. The effect of the greater stringency of regulation of new sources may be to retard the replacement of older, more heavily polluting sources with new less-polluting sources.[8] This differential treatment may, therefore, result in the loss of opportunities to improve ambient air quality.

1.3 Experience with Market-Based Implementation Incentive Options

Experience with the implementation of the bubble procedures has been limited. Exhibits 3 and 4 indicate the regional distribution and types of industrial categories that have been involved in bubble transactions.

Research indicates that the bubble concept holds promise for substantial cost savings. Maloney and Yandle (1980)[9] investigated the savings that could be obtained by applying the bubble concept in 52 DuPont plants. For those plants, they showed that an 85% discharge reduction could be achieved through application of the bubble concept within the same plant at 60% of the cost of achieving that discharge reduction using uniform technology standards. The total savings were estimated to be $63.1 million. When the 52 plants were placed under one so-called regional (or multi-plant) bubble, abatement costs were found to be 86% lower than the costs imposed by uniform technology standards. The total savings were estimated at $91.1 million.

An example of implementation of the bubble in the multi-plant context is found in the Narragansett Electric Company. High sulfur oil (2.2% content) may be used at one plant when the second plant is burning natural gas or is not operating.[10] In comparison to permit conditions requiring the use of 1% sulfur fuel oil in both plants, the Narragansett bubble is said to save $3 million per year.[11]

Offsetting was developed prior to the enactment of the 1977 amendments to the Clean Air Act as an innovative administrative approach to accommodate growth in nonattainment regions. It was formally introduced in a December 1976 EPA interpretive ruling as a set of administrative procedures to allow construction of new or modified sources in nonattainment regions.

EXHIBIT 3
BUBBLE CONCEPT APPLICATIONS BY AIR QUALITY MANAGEMENT REGION*

Region	November 1981	Approved/ Proposed Approval
New England	4	2
New York-New Jersey	9	2
Mid-Atlantic	16	7
Southeast	15	5
North-Central	36	9
South-Central	7	1
Mid-Central	1	1
Rocky Mountain	3	1
Southwest	0	0
Northwest	2	0
TOTAL	93	28

*Source: Environmental Protection Agency, "The Controlled Trader," November 1981.

EXHIBIT 4
BUBBLE CONCEPT APPLICATIONS BY TYPE OF INDUSTRY*

Type of Trade-->	Change in Control			Process Change		Fuel Switch		NA**	Total
Pollutant------>	TSP	VOC	SO_2	VOC	TSP	TSP	SO_2		
Type of Industry									
Steel	10		3				1		14
Other metals	1							1(TSP)	2
Chemical mfg		5	1				2		8
Utilities			1				5		6
Greenhouse							4		4
Coating - paper, tape, wire		4		8				5(VOC)	17
Coating - cans,				17				1(VOC)	18
appliances,autos				8					8
Distillery	2								2
Pulp and paper	3			1	1		1		6
Tires and plastic				2					
Oil			3		1				
Glass	4								
Minerals	1				3			2(TSP)	6
TOTAL	21	9	8	28	5		13	9	93

VOC = Volatile Organic Compounds, hydrocarbons that react with NO_2 to form photochemical oxidant, also called ozone (O_3). TSP = Total Suspended Particulates. SO_2 = Sulfur Dioxide.

*Source: Environmental Protection Agency, "The Controlled Trader," November 1981.

**Information not available by type of trade.

A greater than one-for-one reduction in emissions is required in nonattainment regions and is allowed in PSD regions under offset procedures. The objective of the greater than one-for-one offset requirement is to achieve a net improvement in air quality. By contrast, the bubble procedures require only that discharge reductions have equivalent ambient air quality effects. Offset procedures are based on the recognition that emissions levels for some sources may be reduced below required levels at lower cost than would be incurred to achieve required levels for other sources. Interfirm trades encourage the search for discharge reduction capability. The application of offset procedures is limited. One limitation, as discussed previously, is the requirement for LAER (as opposed to less stringent uniform technology standards such as RACT) as a baseline, which reduces the number of discharge reductions that can be traded.

A recent EPA Status Report on emission reduction banking indicated that "Almost all states had incorporated offset provisions in their SIPs, with about 1,900 offset transactions having taken place."[12] Initial offset transactions involved intercompany transactions or alterations in state or local production operations. In the most recent study on the implementation of the offset program, conducted in 1981, Vivian found that 37 interfirm transactions had been consummated.[13] Most recent offset transactions have reflected internal changes to an existing source in order to expand or build new point sources.[14]

1.4 Offset Banking

Offset banking is the most recent addition to the bubble and offset procedures. The offset procedures were modified in January 1979 to allow the development of banking programs.[15] The Statement represents the first detailed articulation of the banking policy. EPA recognized that discharge permit banking could facilitate the use of both the offset and bubble procedures by providing the capacity to store discharge reductions. Credits can be received by sources that reduce discharges by amounts exceeding reductions required in the SIP. The discharge reductions can be used by the source or sold for use as an offset.

In January 1979 EPA issued interpretive rulings stipulating that a state could assume the role of banker and would be "free to govern the ownership, use, sale, and commercial transactions in banked emission offsets as it sees fit."[16] Pursuant to this ruling several banks have been established to facilitate the offset and bubble procedures.

Since it was established in June 1979, the Louisville bank has processed 22 discharge reductions that exceed reductions required by the SIP. It has undertaken a number of offset transactions. For example, in the summer of 1981, the Borden Chemical Company purchased a 25-ton hydrocarbon permit from the B.F. Goodrich Company.[17] Borden plans to use some of the permit in lieu of meeting more costly uniform technology standards. The cost of the permit was approximately $2500/ton as compared to the least costly control measures of $5800/ton.

The San Francisco Bay Area air quality management region established a bank in January 1980. As of March 1982, 10 applications for emission reduction credits had been received by the San Francisco Bay Area Bank. Of these applications, only three had been approved.[18] Banking programs are also currently in operation in the Louisville, Kentucky and Puget Sound air quality management regions.[19] Programs are also being developed in Massachusetts, Maryland, Louisiana, and Washington.[20] Oregon's comprehensive banking and trading rules were approved by EPA on April 27, 1982.[21]

2.0 THE EMISSIONS TRADING POLICY STATEMENT

"Emissions trading" is a concept of which there may be many variations; it is based on the notion that existing ambient air quality standards may be achieved more effectively and at a lower cost if firms are allowed to adjust their permits by proposing alternative responses to regulation within a market context. At present, the marginal cost of meeting uniform technology standards may vary significantly across an industrial category.[22] Such costs may vary substantially among different plants within the same firm. Yet the existing implementation incentive system does not provide a means for compensating firms for going beyond regulatory obligations.

Trading allows high-cost sources (i.e., sources whose unit pollution abatement costs are high relative to other sources generating and discharging the same residuals) to buy discharge permits from low-cost sources, leading to an equilibrium in which the marginal cost of control for all sources of those residuals in an air quality management region is equal to the market-clearing price for discharge permits.[23]

In addition to the efficiency gains from trading that are possible, the Statement is meant to improve the incentives that firms have to reduce discharges. At present, sources have no incentive to use available technology to reduce their discharges below the limitations specified in their permit to operate. Further, incentives to develop new control technologies are limited. Firms will seek lower cost measures to achieve required discharge reductions, but lack any incentives to develop control technologies that improve upon the current requirements. Allowing trading in discharge permits creates incentives both to innovate and to achieve lower cost reductions by allowing firms to sell "surplus" discharge reductions.

The Statement places restrictions on market transactions in order for an emissions trading system to be consistent with the statutory and administrative framework of the Clean Air Act. The variations on the concept of emissions trading may take many forms in terms of the substantive requirements, the administrative procedures for implementation, and the resources allocated by state and local air quality management regions for program development, management, and enforcement. At the one extreme, there may be a requirement that every discharger meet uniform technology standards before discharge permits may be traded. At the other extreme is the national, regional, or state "bubble" defining the scope of the market with freely tradable permits unrestricted except for the total quantity of discharges allowed in the air quality management region.

There are a number of reasons for the restrictions on ERC transactions. Uncertainty with respect to ultimate effects on the attainment or maintenance of the NAAQS is the basis for placing restrictions on certain types of bubble and offset transactions. Some transactions are restricted because they may involve increases in hazardous pollutants. Other restrictions concern the treatment to be afforded banked discharge permits when an air quality management region changes status from a PSD region to a nonattainment region or from one to another of the three categories of nonattainment regions. (See Exhibit 2.) In particular, should states be allowed to provide certainty that an ERC will not be confiscated or devalued, either while it is banked or when it is sold to another firm? Without some degree of certainty, firms will be reluctant to engage in discharge permit trading.

In addition to these concerns, restrictions on discharge permit transactions may be based on:

- the compliance status of the source seeking to create, trade, or use tradable discharge permits;
- the extent to which the transaction has been assumed as part of the air quality management region's demonstration of "reasonable further progress";
- demonstrated "equivalence" of ambient air quality impacts;
- the effect on baseline discharges;
- the uniform technology standard (if one exists) for the producer or user of the tradable discharge permit;
- the existence of uniform technology standards for the producer or user of the tradable discharge permit; and
- the extent to which the source is included in the inventory of dischargers used by the air quality management agency in developing its SIP.

Establishing an emissions trading program is purely voluntary on the part of the state; EPA offers the Statement as a set of guidelines to be used for establishing any emissions trading program. The Statement supersedes existing regulations governing discharge reductions obtained through application of the bubble procedures and used in bubble, offset, netting, or banking transactions. Exhibit 5 summarizes the extension of existing procedures for the bubble, netting, offset, and banking policies. It uses the same format as Exhibit 2.

As described earlier, PSD regions are either regions that are at the ceiling of the PSD increment or the primary standard, or are regions with some or all of the PSD increment remaining. In those PSD regions that are at either the ceiling of the PSD increment or the primary standard, existing activities may use bubble and offset transactions; this has not been affected by the Statement. The level of control is primarily determined by the air quality

EXHIBIT 5

SUMMARY OF PERMISSIBLE TRANSACTIONS IN EMISSION REDUCTION CREDITS UNDER THE EMISSIONS TRADING POLICY

	EXISTING SOURCES	NEW SOURCES AND MAJOR MODIFICATIONS
PSD REGION		
At ceiling of PSD increment or primary standard	Bubble allowed (unchanged) Offsets allowed (unchanged)	Offsets allowed (unchanged) BACT and NSPS required (must show no violation of increment)(unchanged) Netting allowed to avoid review as new source with possible LAER determination (unchanged) ERC transactions cannot be used to meet uniform technology standards, e.g., BACT, NSPS
Regions with some or all of the PSD increment remaining	Subject to the same requirements as above, with PSD program required but without a requirement for a formal SIP	Subject to the same requirements as above, with PSD program required but without a requirement for a formal SIP
NONATTAINMENT REGIONS		
SIP demonstrates attainment by 1982 (or conditionally approved SIP)	Bubble allowed (unchanged) Offsets allowed (unchanged) RACT may exist as a control requirement for some activities in SIPs that failed to demonstrate attainment on initial submittal (unchanged)	NSPS required (unchanged) LAER required (unchanged) Offsets required (unchanged) Netting allowed to avoid review as a new source with possible BACT determination (unchanged)
SIP not demonstrating attainment by 1982	Bubble allowed (change) RACT required (unchanged) Margin of growth required by use of offsets or an accommodative SIP (unchanged)	Same as above
SIP not demonstrating attainment by 1987; or region without approved SIP that demonstrates attainment	Same as above, with the exception that it is not currently clear whether or how the bubble may be used; likely that installation of uniform technology standards will be required	Same as above

ERC = Emission Reduction Credit

management region. For new activities or major modifications to existing activities, netting and offsetting are allowed with no change resulting from the Statement. In regions that have some or all of the PSD increment remaining, the Statement does not alter the requirements for existing, new, or major modifications to existing sources.

Nonattainment regions are divided into three administrative categories. For regions with SIPs that demonstrate attainment by 1982, the requirements for existing sources with respect to the bubble, offset, and RACT baselines are unchanged. For existing sources, ERCs may be purchased to meet RACT discharge limitations. For new sources or major modifications to existing sources, the required uniform technology standards are unchanged. Trading of Emission Reduction Credits cannot be used to meet the uniform technology standards for NSPS, LAER, and BACT.

For regions with SIPs that do not demonstrate attainment by 1982, an existing source not in compliance with SIP requirements may now use the bubble to come into compliance. Sources that are in compliance may also, for the first time, use the bubble to reduce costs.

For regions with SIPs not demonstrating attainment by 1987, or regions without approved SIPs that demonstrate attainment, it is likely that installation of equipment that meets uniform technology standards will be required in order to meet the NAAQS. The requirements for new sources and major modifications to existing activities in these regions are not changed by the Statement.

Three components of any emissions trading program established pursuant to the Statement are the creation of an ERC, its storage, and its use in a trade. Emissions trading programs must limit credit to those discharge reductions that are surplus, enforceable, permanent, and quantifiable.

2.1 The Creation of Emission Reduction Credits

The Statement requires that ERCs created from bubble transactions obtain federal regulatory approval either through a generic SIP provision that "preapproves" specific categories of transactions, or through a case-by-case revision to an SIP.[24]

A generic SIP provision establishes rules and procedures that may be adopted by the states to govern specific categories of transactions and avoid case-by-case federal determinations as SIP revisions. The generic rule must incorporate the following information in order to be approved by EPA:

- applicable discharge limitations;
- relevant testing methodologies;
- recordkeeping and reporting requirements;
- permit conditions, including operating or production limits, compliance agreements, consent decrees, or other legally binding documents relevant to the firm.

Generic rules are limited to transactions that do not increase baseline discharges. In addition, the generic rules may specify exemptions from SIP revisions for the following transactions involving:

1. de minimis sources, i.e., those sources that discharge less than 100 tons/year after control, with no increase in baseline discharges;

2. "pound for pound" transactions involving VOC or NO_x discharges;

3. transactions within the same immediate vicinity among sources that discharge SO_2, CO, or TSP -- subject to the additional constraint that discharges decrease at the source with the lower effective plume height;

4. other transactions among dischargers of SO_2, CO, or TSP subject to the constraint that total discharges do not increase and certain modeling requirements are met.[25]

The first requirement for creating ERCs is that only surplus discharge reductions not legally required by the SIP or by uniform technology standards may qualify.[26] The legal limitation is expressed as the "baseline." The baseline used to define a surplus discharge reduction must be consistent with the baseline assumptions used in development of the SIP. In nonattainment regions either actual or allowable discharge levels as specified in the SIP may be used. The term "allowable" refers to discharge levels that are in the operating permit of the source. The level of allowable discharges in the permit may differ from the operational production characteristics (e.g., number of hours, inputs, product specifications) of the source. A total allowable discharge level was used in many SIPs with no attempt made to determine whether this level is the "actual" or monitored level discharged by the source. Even "actual" may have any of several definitions:

- discharges attributable to the source in the SIP;

- an average discharge level calculated for a representative period of operation;

- monitored discharge levels; or

- discharge levels estimated from representative discharges for a specific type of equipment or production process.

The substantial differences between actual and allowable that are possible provide cause for concern in determining how "surplus" should be defined. (See Section 3.2.)

The baseline problem has been addressed administratively in the Statement. Where RACT is defined in the SIP, it will be the baseline.[27] For cases in which RACT has not been defined for the source category, an acceptable RACT limitation may be agreed upon or actual discharges may be used.[28]

In attainment regions, the baseline for determining ERCs must be consistent with air quality management regulations established in the PSD program under §110[29] and Part C of the Act.[30] In attainment regions, the baseline is "actual" discharges, as defined above.

To protect the public's interest in emissions trading, transactions must be enforceable by the air quality management agency, the EPA, and citizen litigants. Transactions that are federally approved on a case-by-case basis or that meet the federally approved generic SIP provisions are automatically enforceable by EPA. Holders of an ERC are protected from violations by the creator of the ERC. Once an ERC has been used by another source to meet a permit requirement, any violation of the conditions under which the ERC was created would result in an enforcement action against the source that produced that ERC, not the activity that used the ERC.

2.2 The Trading of Emission Reduction Credits

Exhibit 5 summarizes permissible transactions in ERCs. An ERC may be transferred in whole or in part through administrative procedures governing the bubble, netting, offset, and banking policies. Transactions are limited to exchanges in the same criteria pollutant.[31] §112 of the Act requires that all sources must meet applicable regulations for hazardous air pollutants (called National Emission Standards for Hazardous Air Pollutants [NESHAP]).[32] An activity may not use bubble transactions to meet these requirements, nor increase discharges of NESHAP pollutants.[33] For NESHAP pollutants that have been designated, but are not yet subject to regulations, states may allow transactions consisting of equivalent increases and decreases if the sources are reasonably close geographically.[34] States may allow emissions trades in which reductions in NESHAP pollutants compensate for increases in non-hazardous discharges. For example, a reduction in benzene discharges may be traded for an increase in a non-hazardous pollutant.

With the Statement, bubble transactions may now be used (except for NESHAP) by existing sources either to attain compliance with current discharge limitations or to meet newly imposed uniform technology standards such as RACT. ERCs may be used by new or expanding sources as offsets in nonattainment regions, or to avoid violating a PSD increment. ERCs may not be used to meet BACT standards for new sources in PSD regions or LAER standards for new sources in nonattainment regions. They may, however, be used by sources undergoing expansion or modification to "net out of" new source review procedures in both attainment and nonattainment regions. Such sources may be held to be not subject to BACT in PSD regions or LAER in nonattainment regions. However, new sources and major modifications to existing sources must meet NSPS if a NSPS exists for that source. Netting may mean only that the more stringent uniform technology standards (LAER or BACT) are not required. But at a minimum, a new source or major modification to an existing source must install NSPS technology.

In summary, ERCs may be traded to meet RACT requirements by existing sources; ERCs may not be traded to meet NSPS, LAER, or BACT. Bubble procedures have not been extended to new sources or major modifications to existing sources.[35] A new source may use netting procedures only to avoid new source review and possible LAER or BACT determination. This category of sources must still install NSPS technology. Bubble procedures may be used by existing activities to create ERCs for their own use or for sale to other activities only after uniform technology requirements have been met. The question of whether EPA could have allowed ERC transactions to meet uniform technology standards has been addressed by Levin.[36] Restricting ERC transactions to existing activities and requiring uniform technology standards as baselines may limit the cost-effectiveness of the Statement in meeting the ambient air quality standards.

2.2.2 "Equivalent" Ambient Impacts

In nonattainment regions, transactions cannot contribute to a violation of a standard or prevent the planned removal in an SIP of an existing violation. In attainment regions, transactions cannot violate a PSD increment or an ambient air quality standard. The Statement requires that the proposed purchaser and user of the ERC demonstrate "equivalence" (i.e., that no increase in regional ambient air quality concentrations will occur if the transaction is consummated). In addition, for nonattainment regions offset transactions must be consistent with reasonable further progress toward attainment. Three levels of air quality modeling are required for sources to demonstrate the equivalence of transactions in TSP, SO_2, or CO ERCs.[37] Level I entails no modeling if the proposed TSP, SO_2, or CO transaction does not result in an increase in baseline discharges. The criteria for Level I are that the point sources are in the same "immediate vicinity," and the effective plume height of the source that increases discharges is greater than that of the point source that decreases discharges. The air quality management region may consider sources within a distance of up to 250 meters to be in the same "immediate vicinity."

Level II and Level III modeling requirements concern transactions that do not fall within generic rules. Level II air quality modeling requires limited dispersion modeling for ERC transactions that would generate "significant" increases in pollutant discharges. "Significant" is defined as increases of 10 ug/m^3 for the 24-hour standard for TSP; 13 ug/m^3 (24-hour) for SO_2; and 575 ug/m^3 (8-hour) for CO. These parameters (referred to by regulators as "modeling triggers"), originally developed in the PSD regulations,[38] now apply to all ERC transactions.[39]

Level III requires full dispersion modeling of all sources in the area of impact if the actual or allowable baseline discharges increase above Level II limitations as a result of a proposed transaction or if that transaction will have a significant air quality impact.

The air quality management region may use the generic trading rule to exempt certain classes of emissions trades from SIP revisions. For example, bubble transactions that meet a valid generic rule incorporated in the SIP do not "change" the SIP and do not require SIP revisions.[40] Netting transactions do not require individual SIP revisions.[41] However, open dust transactions (relevant in steelmaking) may require a SIP revision under the Statement.[42] The transaction requires the source that uses an ERC to undertake a post-approval monitoring program to further evaluate the impact of the transaction.

Transactions between small dischargers are exempt from SIP revisions because only minor quantities are involved.[43] Dischargers whose potential to discharge is less than 100 tons per year are considered small dischargers.[44] Such transactions are called "de minimis."[45]

VOC and NO_x transactions are exempt owing to their "mixing bowl" characteristics.[46] All such discharges within a broad area are considered comparable, regardless of stack height or topography. All VOC or NOx trades may be consummated under a generic rule that assures no "net" increase in discharges. Otherwise an individual SIP revision is required.

Due to the reactivity of SO_2, CO, and TSP with other residuals in the ambient air, the ambient impact of emissions trades in these pollutants depends on topography and discharger characteristics. Transactions may be exempted from air quality modeling requirements if they fall within Level I and may be treated through a generic rule in the same manner as transactions involving VOC and NO_X.[47] If the sources are located in the same immediate vicinity and discharges decrease at the source with the lower effective plume height, the Statement assumes that equal increases and decreases will minimize localized ambient impact.

2.2 Relaxation of Existing Regulatory Implementation Incentives

The Statement alters the existing implementation incentive system in a number of important ways. First, it removes the restriction on the application of bubble procedures for a source to attain initial compliance.[48] Prior to the Statement, bubble procedures required that a source agree to a SIP compliance schedule in order to be allowed to propose alternative discharge limitations through bubble transactions. Compliance deadlines for VOC dischargers may be extended on a case-by-case basis as part of the air quality management region's approval of the proposed bubble transactions. The Statement allows states to grant extensions for compliance under generic rules without case-by-case SIP revisions.[49] The only constraint on the development of generic rules for extensions is that they be consistent with reasonable further progress. The Statement allows for the development of generic rules for approval of bubble transactions in pending enforcement actions so long as there is a mechanism for EPA and court approval.[50]

2.3 The Banking Procedures

Air quality management regions may establish their own banking programs without following the Statement guidelines. However, each use of an ERC must be processed as a SIP revision. In the Statement, the bank serves a number of roles. It accepts and evaluates requests to certify ERCs, designates ownership righ's, acts as a clearinghouse for credits, and controls and tracks the use of ERCs through the permitting process.[51]

The banking rules specify the life of a permit. They may also stipulate reversion to the air quality management region upon duration of the period. The Statement requires that generic SIP rules be precise about what kinds of adjustments may take place to ERC values. During the time the ERC is held in the banking system, it may be subject to several types of discounting:

- when more stringent control requirements are adopted after the regulation of the ERC; or
- when new information that results in more accurate estimates becomes available to the air quality management agency;
- if the creating source does not comply with its adjusted permit; or
- if the status of the region changes to nonattainment, or an increment violation occurs.

In addition, the bank may change offset ratios, thus altering the quantitative value of ERCs required for a transaction. The Statement provides several options to the air quality management region should a revision in permitted discharge become necessary:[52]

- full preservation of ERCs;
- full preservation of values, and a moratorium on the use of permits obtained from the bank;
- discounting on a case-by-case basis the quantity of applicable ERCs that may be used; or
- discounting ERCs by the same percentage across the board.

3.0 POLICY ISSUES IN THE EMISSIONS TRADING POLICY STATEMENT

The effectiveness of the Statement in meeting and maintaining the ambient air quality standards will depend on source response to the implementation incentive system within which the Statement must fit. The Statement does not prevent discounting of the quantitative values of discharge reductions both prior to certification of a discharge reduction as an ERC and before the discharge reduction is used to modify the permit of the purchaser.[53] On the other hand, nothing precludes an air quality management agency's deciding to guarantee the quantitative values of ERCs for a specified period of time.

3.1 Uncertainty in Emission Reduction Credit Values

The ERC is a "contingency" property right that may be used to adjust the discharge permit of an existing source or to establish the permit of a new or modified source once applicable uniform technology standards have been met. The term "contingency" is used because the quantitative dimension of the ERC for specific types of transactions is uncertain; its quantitative dimension is a function of uniform technology standards and/or the attainment status of the air quality management region.

Discounting in the absence of specific rules creates uncertainty in ERC values and will reduce the expected value to a firm for creating discharge reductions. Deficiencies in the existing air quality management system lie at the root of the problem. In the SIP process, EPA has allowed the air quality management regions significant latitude in permitting or in disallowing particular types of abatement alternatives, e.g., fuel switching, shutdowns.

3.2 "Paper" Emission Reduction Credits

Another source of uncertainty in the creation of ERCs results from the way discharge baselines are measured in SIPs. SIPs may be based upon "actual" discharges or "allowable" discharges.[54] "Actual" discharges refer to monitored discharge levels. "Allowable" discharges, on the other hand, refer to maximum (or "upper limit") discharge levels that are allowed in a SIP for specific sources. They overestimate actual emissions for sources that operate at less than full capacity. While a source can legally discharge to SIP allowable limitations, the creation of ERCs using allowable discharges as baseline may lead to reductions on paper, but yet a deterioration in ambient air quality. For example, assume that a source has a SIP allowable discharge limitation of 100 tons per year based on 24 hours of operation and that the SIP was based on actual discharges to determine the necessary discharge reductions to meet ambient air quality standards. If the source historically operated at this 100 tons per year level when the SIP was approved, but then reduced discharges to 80 tons per year, a surplus discharge reduction of 20 tons per year would qualify for credit. Consequently, if the source's actual discharges at the time the SIP was developed had been 50 tons per year, based on an average actual daily operation of 12 hours, reducing the activity's legally enforceable operating hours to 12 hours would create a "paper" reduction of 50 tons per year. Of course, the actual discharge reduction would be zero. To determine which baseline is appropriate for emission trading, the air quality management region must examine the assumptions used in the development of the SIP.

We would recommend that the generic rules require the use of actual discharge levels in SIP development. However, it might also be argued that "paper" credits would not occur if the following three conditions are met: (1) maximum allowable emissions are the basis for determining the total units of permissible discharge for a region; (2) individual permits are denominated in maximum allowable emission levels; and (3) sources are constrained to meet the permit conditions as stated.

3.3 Reduction Credit Ownership After Shutdowns

Another element of uncertainty relates to the ownership of ERCs created from plant shutdown or curtailment of activities. Shutdowns can be a plentiful source of ERCs. Technically, nonattainment regions may not be allowed to grant ERCs to firms for shutdowns if the nonattainment regions have already counted specific shutdowns in meeting federal requirements to demonstrate reasonable further progress toward attainment. If air quality management regions are not restricted from assuming shutdowns to meet the requirement of demonstrated reasonable further progress toward attainment, such assumptions effectively constitute appropriation of the discharge reduction without compensation. One can imagine negotiations among state, local, and federal authorities, and the owners of the shutdown as to which entity may rightfully sell the discharge reductions achieved from shutdowns. One possible solution might be to require the states to compensate firms that shut down if specific shutdowns were assumed in the development of the SIP. However, this might in turn create other problems with the system of implementation incentives.

3.4 Changes in Regional Attainment Status

However, a major concern in the Statement is what will happen to the quantity of banked ERCs if the status of the air quality management region changes from attainment to nonattainment, or if a violation of a PSD increment occurs. Several resolutions of the problem are possible. One might argue that protection of banked ERCs ought to be a priority in the Statement. After all, the banked ERC represents an improvement in air quality, since discharges are being withheld from current ambient loadings. One way to handle the problem would be to preserve banked ERCs and make revaluation a measure to be used only when no further emission reductions can be squeezed from other existing sources. Another way to reduce uncertainty would be to limit revaluation to some fixed percentage of the value of the ERC, e.g., 10%, 20%, or 33%, with any further required regional reduction borne proportionately by all existing dischargers.

Ostensibly, EPA already has the power to regulate the number of units of permissible discharge for a region when it challenges a SIP estimate of discharge reductions necessary to meet the ambient air quality standards. For example, EPA may argue that the state's calculation of 5000 kg of SO_2 is in error and that only 4000 kg of permissible units of SO_2 discharge are available if the ambient air quality standards are to be met. Or, if EPA does not think that conditions for a specific permit are sufficiently stringent, it can prevent the state from issuing the permit. Consequently, the power to adjust units of permissible discharge and permit conditions in a region is something that EPA already posseses.

3.5 Uniform Technology Standards as Baselines

Uniform technology standards (such as RACT, BACT, LAER, or NSPS) are based on the notion that specific production processes can be standardized and defined as a metric of discharge. All plants of the same type, regardless of their location, are required to meet the same discharge baseline, despite the effect of their uniformly regulated discharges on resulting ambient air quality parameters. In practice, this has been cited by some analysts as allowing policymakers to push uniform technology standards beyond the point of ecological justification.[55]

Arguments often advanced in favor of uniform technology standards are based on equal treatment and the certainty of requirements for activities in industrial planning and siting decisions. However, the rhetoric of "uniformity" is misleading. Uniform technology standards are developed as a set of rules of general applicability; they cannot distinguish the impacts on ambient air quality from siting different types of activities in different regions of the country. Uniform technology standards also encourage an accounting of the installation of devices as the measure of attainment or improvement in ambient air quality, as opposed to actual monitored changes in the ambient air.

4.0 SUMMARY AND CONCLUDING COMMENTS

In Section 1 of this paper the existing regulatory implementation incentive structure for stationary source dischargers was described. Requirements for uniform technology standards were found to vary in stringency according to (1) whether the discharger is an existing source or a new or modified source, and (2) the nonattainment or PSD status of the region. Implementation incentive options (the bubble, offsets, and netting) differ according to the type of source and attainment status of the region. Banking programs for VOC, SO_2, and TSP are in limited use in Louisville and San Francisco. The Puget Sound air quality management region has an active banking program. As of November 1981, numerous deposits had been made with no reported withdrawals.[56] As of that date, there had been 93 bubble applications (of which 28 had been approved) and 37 interfirm transactions through offset procedures.[57]

Section 2 of the paper contained a discussion of the Statement as a logical extension of administrative innovations already in limited use. The objective of trading ERCs is to improve the implementation incentives that firms have to reduce discharges. The Statement encourages firms to use available technology to reduce discharges below the applicable legal limitations specified in their permit and in uniform technology standards. By being allowed to sell "surplus" discharge reductions, firms have the implementation incentive to innovate and thereby achieve lower abatement costs. The "payoff" to the region is the opportunity to achieve at least cost the region's limitation on total units of permissible discharge necessary to meet the NAAQS.

The Statement provides guidelines for the air quality management regions to develop "generic" SIP provisions that allow ERC transactions through bubble, offset, netting, and banking procedures in the absence of case-by-case federal approval of transactions as SIP revisions. In order for an emission reduction to qualify as an ERC, it must be surplus, enforceable, permanent, and quantifiable. In nonattainment regions demonstrating attainment by 1982, baselines must be consistent with the assumptions used in the development of the SIP. Other nonattainment regions are constrained to use baselines that do not jeopardize attainment by the statutory deadlines. For PSD regions, actual emissions are normally the baseline, but allowable emission levels may be used if proper consideration of increment consumption is assured.

ERC transactions are required to be consistent with attainment and/or maintenance of the NAAQS. Constraints on transactions are designed to reduce uncertainty with respect to the ultimate effects of trades on ambient air quality. The Statement imposes a number of constraints. First, trades are limited to the same pollutant, e.g., reductions in TSP are traded for increases in TSP. Second, ERC transactions must demonstrate equivalent ambient effects. Owing to their "mixing bowl" characteristics in the ambient air, "pound for pound" trades in VOC or NO_x are treated as having equal ambient impacts. Transactions of "nonmixing bowl" residuals, SO_2, TSP, or CO, are required to demonstrate equivalent ambient effects by meeting varying levels of dispersion modeling requirements. Third, transactions may not increase discharges of hazardous pollutants. Nor may the bubble procedures be used to meet discharge requirements for hazardous pollutants. Fourth, new sources are not allowed to use ERCs to meet applicable uniform technology standards, e.g., NSPS, BACT in PSD regions, or LAER in nonattainment regions.

Several provisions of the Statement relate specifically to the use of bubble transactions to create ERCs. First, the Statement allows regions that lack approved SIPs that demonstrate attainment to use bubble procedures. However, such transactions may not jeopardize the timely attainment of the NAAQS. Second, sources are allowed to use the bubble procedures to achieve compliance. Prior to the Statement, sources had been required to initiate compliance agreements (including ordering equipment) to meet the original SIP emission limitations even while alternative emission limitations were proposed in bubble applications. Third, generic SIP rules concerning discharge transactions may provide criteria for granting compliance extensions in VOC and CO bubble applications. Finally, open dust (TSP) transactions may be approved based on demonstration of acceptable modeling and/or post-installation monitoring. The ERC bank will accept and evaluate requests to certify ERCs. It will maintain a registry of available ERCs by pollutant category, source category, and location. The role of the bank is to act as a clearinghouse for ERCs, implement ERC transactions, and track the use of ERCs through the permitting process. For regions that change status with respect to the number of available units of permissible discharge, the provisions of generic trading rules allow for:

- full preservation of ERC quantitative values;
- a moratorium on ERC transactions;
- discounting of ERC values on a case-by-case basis; or
- across the board discounting of ERCs in proportion to additional discharge reductions to be imposed on sources in the region.

Section 3 of the paper contains a discussion of policy issues in the Statement that create uncertainty that may limit the cost-effectiveness of proposed changes in the regulatory implementation incentive structure. Four policy issues were discussed. First, inconsistency in the use of "actual" and "allowable" baselines for determining "surplus" discharge reductions may lead to "paper ERCs" that lead to deterioration in ambient air quality. Determination of the appropriate baseline will require close examination of the assumptions used in SIP development. Second, nonattainment regions often use anticipated shutdowns in the required demonstration of reasonable further progress (RFP) toward attainment. Technically, nonattainment regions may not grant ERCs to the owners of sources that cease or curtail operations if such reductions were used in RFP demonstrations. Consequently, with restrictions on the availability to the region of purchasable ERCs from shutdowns, opportunities for the installation of innovative and new lower discharging sources by expanding firms may be lost.

Third, the Statement leaves uncertainty with respect to ERC values in regions where the attainment status changes to reflect a deterioration of ambient air quality. The development of rules concerning what happens to banked ERCs in such instances will affect the incentive to produce and bank ERCs. Finally, there was a discussion of the use of uniform technology standards as baselines for the creation and use of ERCs. Requiring that such stringent limitations be met before an emission reduction can be certified as an ERC will mean that some cost-effective trades will be missed.

In conclusion, it is clear that the Emissions Trading Policy Statement does expand to some degree the use of a market-based approach to air quality management. However, because of restrictive statutory provisions, the Statement limits the efficiency of trading primarily to existing sources. The general expansion of the administrative procedures for the bubble in PSD regions with some or all of their PSD increment remaining represents the only concession from current regulations to new or major modified sources. Some may view this expansion as an appropriate move in a desirable direction. Others, however, will argue that the Statement will be of limited usefulness until it can be made applicable to all sources in all air quality management regions, regardless of the attainment status of the region. Whether one applauds the clear signal that the Administration is finally prepared to initiate market-oriented regulatory reforms or rues the many constraints that were built into this first endeavor, is largely a function of one's own predilection toward the dispatch with which government ought to convert economic theory into real world regulatory practice. What is apparent is that the current EPA Policy Statement represents at the least a marked consolidation and improvement of disparate components of the nation's air quality management implementation incentive structure.

FOOTNOTES

1. U.S. Environmental Protection Agency (EPA), "Emissions Trading Policy Statement: General Principles for Creation, Banking and Use of Emission Reduction Credits," 47 FR 15076, April 7, 1982 [hereafter, "Statement"].
2. Air quality management agency is defined to include federal, state, or local authorities designated to develop or implement air quality management regulations.
3. 47 FR 15078.
4. 42 U.S.C. §7410(a)(2)(B).
5. Definitions of each of these terms, as well as of other terms used in this paper, are contained in the Glossary.
6. 44 FR 71779.
7. ibid.
8. Morrison.
9. Maloney and Yandle, p. 50.
10. Drayton.
11. ibid.
12. EPA, Office of Policy and Resource Management, "Emission Reduction Banking" (Status Report: April 22, 1982 [hereafter, "Status Report"]).
13. Vivian and Hall.
14. ibid.
15. 44 FR 3280.
16. ibid.
17. EPA, The Controlled Trader, Vol. 1, No. 3, November 1981 [hereafter, "Controlled Trader"], p. 2.
18. U.S. General Accounting Office, "A Market Approach to Air Pollution Control Could Reduce Compliance Costs Without Jeopardizing Clean Air Goals," PAD-82-15, March 23, 1982, p. 64.
19. Status Report.
20. ibid.
21. 47 FR 18005.
22. Maloney and Yandle, p. 50.
23. See, e.g., Montgomery (1972), Noll, Tietenberg, and Dales.
24. 47 FR 15084.
25. 47 FR 15085.
26. 47 FR 15080.
27. ibid.
28. ibid.
29. 42 U.S.C. §7410.
30. 42 U.S.C. §7410-7491.
31. 47 FR 15082.
32. 42 U.S.C. §7412.
33. 47 FR 15082.
34. ibid.
35. ASARCO, Inc. v. EPA (11 ERC 1129) held that the bubble procedures could not be used to meet NSPS requirements.

FOOTNOTES
(continued)

36. Levin.
37. 47 FR 15082.
38. 45 FR 52709.
39. 47 FR 15081.
40. 47 FR 15081.
41. *ibid.*
42. 47 FR 15083.
43. 47 FR 15084.
44. *Alabama Power v. Costle*, 13 ERC 1993, 2010 (D.C. Cir. 1979).
45. 47 FR 15085.
46. *ibid.*
47. *ibid.*
48. 47 FR 15083.
49. *ibid.*
50. *ibid.*
51. *ibid.*
52. 47 FR 15084.
53. See, e.g., Brokering Emission Reduction Credits: A Handbook, EPA, 1980.
54. 45 FR 52700.
55. Ackerman and Hassler.
56. Status Report.
57. Controlled Trader.

APPENDIX A

GLOSSARY OF TERMS AND SYMBOLS

Code	Term and Definition
	Accommodative SIP. See SIP.
	Activity. An economic entity at a particular location that discharges residuals. "Firms" may have many activities (i.e., multiple sites), and a single activity may have many sources of residuals. An industrial plant, a farm, a mining operation, a restaurant, an office building, a household, a management unit of a national forest, a motor vehicle -- each is an activity and each generates residuals according to some time pattern.
	Air Quality Management Agency. The government agency directly responsible for ambient air quality in the area around the activity. The agency may have any of several names -- e.g., environmental protection, pollution control -- but its basic purpose is to meet the ambient air quality standards.
AQMR	Air Quality Management Region. The geographical area over which the cognizant air quality management agency has regulatory jurisdiction. The region is responsible for submitting a plan to achieve the NAAQS under §110 of the Clean Air Act.
	Air Quality Management Strategy. A program or set of programs consisting of some or all of the following elements: o physical measures for reducing discharges of gaseous residuals from activities; o implementation incentive systems that induce the adoption of measures to reduce discharges; o distribution of responsibilities among governmental agencies for imposing implementation incentives, monitoring, planning, and enforcement.
AAQS	Ambient Air Quality Standard. A regulatory limitation establishing the maximum allowable concentration of pollutants in the ambient air.
BACT	Best Available Control Technology. A discharge limitation based on the maximum degree of reduction of each residual, after taking into account energy, environmental, and other economic costs. BACT is determined on a case-by-case basis. The Clean Air Act requires BACT in PSD regions for new activities.
	Bubble Concept. Any attempt in residuals management to place an imaginary bubble over an activity's multiple point sources and to treat the activity administratively as a single unit process subject to a maximum discharge limitation.

APPENDIX A

GLOSSARY OF TERMS AND SYMBOLS
(continued)

Code	Term and Definition
	Bubble Procedures. Administrative regulations that allow point sources within an activity to increase discharges beyond currently applicable uniform technology standards or permit conditions if a greater or compensating reduction in discharge is accomplished at another point source within the same activity.
	Command and Control. A regulatory scheme based on rules that apply specific technical performance standards -- generally based on known feasible control technology -- to every discharge point within a regulated process.
	Compliance. To be "in compliance" means that an activity has met the requirements of the relevant air quality management agency. However, such requirements vary from one-time installation of specified end-of-pipe measures to actual continuous compliance with all conditions of a permit.
	Continuous Compliance. An activity is in continuous compliance if, on a day-to-day or hour-to-hour basis in some cases and/or with respect to some residuals, the performance of the activity is within the limits specified in the permit, e.g., discharges of gaseous or liquid residuals are within the limits specified, quality of raw material input or product output is within the limit specified.
CTG	Control Technique Guidelines. Guidelines issued by the EPA to assist state and local air quality management agencies in determining RACT for achieving and maintaining air quality standards through control of existing activities.
CT	Controlled Trading. A regulatory approach that puts the profit motive to work for residuals management, allowing any activity to meet its pollution control responsibilities by securing required emission reductions from any points within its own or other facilities, so long as air quality and the enforceability of the resulting trade in levels of control remain equivalent. [Recently redesignated "Emissions Trading"]
	Criteria Pollutants. Any one of seven residuals subject to the NAAQS, i.e., TSP, SO_2, CO, NO_2, O_3, HC, and Lead. The 1970 Clean Air Act Amendments required that documents (called "criteria documents") be developed for these pollutants as the basis for establishing the NAAQS.
ERC	Emission Reduction Credit. The legal entity that is used by an activity to satisfy legal requirements for discharge permits by existing, modified, and new point activities.
ET	Emissions Trading. See "Controlled Trading."
	Equivalent Ambient Impacts. Transactions in ERCs are constrained to meet ambient impact tests. In nonattainment regions, transactions cannot contribute to a violation of a standard or prevent the planned removal in

APPENDIX A

GLOSSARY OF TERMS AND SYMBOLS
(continued)

Code	Term and Definition
	a SIP of an existing violation. In PSD regions, transactions cannot violate a PSD increment or a NAAQS. Varying degrees of air quality modeling are required for activities to demonstrate the equivalence of transactions in ERCs. Level I entails no modeling if the proposed TSP, SO_2, or CO transaction does not result in an increase in baseline discharges. Level II requires limited dispersion modeling for "significant" ambient air quality effects. "Significant" is defined as increases of 10ug/m^3 for the 24-hour standard for TSP; 13 ug/m^3 (24-hour) for SO_2; and 578 ug/m^3 (8-hour) for CO. Level III requires full dispersion modeling of all sources in the area of impact if the actual or allowable baseline discharges increase above Level II limitations as a result of a proposed transaction or if that transaction will have a significant air quality impact.
	Firm. The relevant context for decisionmaking. Firms may be single-plant or multi-plant. For an individual activity, which may be either one plant of a multi-plant firm or one sub-unit of a plant (whether a single-plant or multi-plant firm), decisions concerning the response to the incentives of regulatory programs are often taken within the context of the entire company.
	Implementation Incentive System. The set of incentives and disincentives for residuals management as seen by the manager of the activity. The implementation incentive system has five components: o a definition of compliance; o rules, including regulations, charges, and subsidies; o methods for measurement of discharges or surrogates; o inspection and monitoring procedures, by which the agency uses the measurement methods; and o sanctions, which can be applied to activities that are not in compliance.
LAER	Lowest Achievable Emission Rate. The most stringent discharge limitation contained in any SIP or achieved in practice. LAER technology is intended to be more stringent that BACT or NSPS. It is defined by the AQMR and is required in nonattainment regions. Determination of LAER is not constrained by cost considerations.
	Marketable Permit System. An environmental quality management strategy based on the determination of a total permissible discharge limitation for a region and the sale of rights to discharge units of permissible discharge by activities within the region.

APPENDIX A

GLOSSARY OF TERMS AND SYMBOLS
(continued)

Code	Term and Definition
	Mixing Bowl. Refers to the reactivity of a given residual with other residuals in the ambient air; the impact of the discharge on ambient concentrations on the residual is not affected by the location of the discharge within the region. This has been assumed to be valid for HC and NO_x. SO_2, TSP, and CO are considered to be non-reactive or "non-mixing bowl" residuals. If a mixing bowl condition exists, the locations of activities do not have to be explicitly considered in the development of air quality management strategies.
	Modification. See NSPS.
NAAQS	National Ambient Air Quality Standards. As measured, the level of key indicators in the environmental media outside the boundaries of the regulated activities. It is assumed that ambient air quality standards have been set and that government agencies are responsible for enforcing those standards and monitoring ambient air quality levels. NAAQS have been established for seven pollutants: CO, SO_2, HV (VC), NO_2, O_3, Total Suspended Particulates (TSP), and Lead. Primary and secondary standards have been set for each pollutant. For CO, NO_2, O_3, HC, and Lead the primary standards are identical to the secondary standards (see Exhibit 1). Primary NAAQS are designed to protect the public health. Secondary NAAQS are more stringent for SO_x and TSP and are designed to protect the public welfare from any known or anticipated adverse effects.
	Netting. A set of administrative procedures that allows an existing source, which increases discharges through modification, to apply the bubble concept in order to avoid new source review, BACT determination, or construction ban. Netting is allowed in nonattainment and PSD air quality management.
NSPS	New Source Performance Standards. Technical performance standards that apply to new, modified, and reconstructed activities. Modifications are defined as changes that increase discharges. Reconstructions are defined as changes in activities that cost more than fifty percent of the expenditures that would be required on a new source. NSPS apply to entire plants, a process within a plant, or a piece of pollution control equipment. An NSPS for a source category must be established at the best level of discharge reduction that is technically achievable, taking into account costs, energy use requirements, and health and welfare effects.
	Nonattainment Region. An air quality management region in which one or more NAAQS are being violated. Such regions are subject to more stringent residuals management requirements.

APPENDIX A

GLOSSARY OF TERMS AND SYMBOLS
(continued)

Code	Term and Definition
	Offset Procedures. New or modified sources expand in nonattainment or PSD regions through interfirm trading of discharge reductions. The activity is required to o install LAER; o comply with other point source requirements within a multi-plant firm; and o obtain reductions below applicable legal discharge reduction limitations.
	Original Compliance. An activity is considered to have achieved original compliance with the conditions specified in a permit to discharge when the physical measures -- including types of inputs -- have been acquired, installed, and are operating to achieve the discharge levels and/or other major conditions specified in the permit.
	Permit. The codification of the formal requirements placed on the activity by the air quality management agency.
	Point Source. See "Source."
PSD	Prevention of Significant Deterioration. Provisions of the 1977 Amendments to the Clean Air Act that establish three classes of attainment areas. These provisions prevent existing ambient air quality with respect to sulfur oxides and TSP matter from deteriorating more than an established amount, called a PSD increment.
RACT	Reasonably Available Control Technology. Discharge limitation that represents the lower limit that a particular existing source is capable of meeting by applying control technology that is reasonably available considering technological and economic feasibility.
	Reconstruction. See NSPS.
	Regulations. Legally enforceable requirements used by air quality management agencies to achieve ambient air quality standards and goals. Specifically, they include requirements on the behavior of an activity (e.g., the imposition of discharge limitations, equipment specification, product specifications, and administrative charges and/or subsidies). The objective of regulation is to change the behavior of individual activities.
	Residual. A material or energy output nonutilizable by the activity responsible for its generation. For that specific activity it has zero value or a value less than the cost of its recovery and transport for use in the same or another activity. A residual discharge to the air, water, or land may or may not be a pollutant.

APPENDIX A

GLOSSARY OF TERMS AND SYMBOLS
(continued)

Code	Term and Definition
SIP	State Implementation Plan. The legal mechanism, subject to approval by the Environmental Protection Agency, by which a state proposes to achieve and maintain the ambient air quality requirements of the Clean Air Act. The SIP specifies discharge reductions from mobile and stationary sources necessary to meet ambient air quality standards in an air quality management region. A "conditionally approved SIP" has been found acceptable to EPA with reservations concerning additional measures that may be required to meet the NAAQS. An "accommodative SIP" imposes unequal residuals management requirements on activities of the same category within a region. A large proportion of abatement may be placed on a small number of activities in the region while other activities are subject to few control requirements.
	Uniform Technology Standards. Sationary source discharges are required by the Clean Air Act to adopt state-of-the-art residuals management techniques or to meet technical performance standards for physical control measures. Such technical performance standards in descending order of stringency include LAER, BACT, and RACT.
VOC	Volatile Organic Compounds. Hydrocarbons that react with NO_2 to form photochemical oxidant (O_3).

APPENDIX B
REFERENCES

Ackerman, B.A. and Hassler, W.T., *Clean Coal/Dirty Air* (New Haven: Yale University Press, 1981).

Anderson, Jr.,R.S., Reid, R.O., Seskin, E.P. et.al., "An Analysis of Alternative Policies for Attaining and Maintaining a Short Term NO_2 Standard." A Report to the Council on Environmental Quality prepared by MATHTECH, Inc. (Princeton, NJ, 1979).

Arthur Anderson and Co., Cost of Regulation Study for The Business Roundtable, (March 1979).

Atkinson, S.E. and Lewis, D.H., "A Cost-Effectiveness Analysis of Alternative Air Quality Control Strategies," *Journal of Environmental Economics and Management*, I (1974).

Baumol, W., and Oates, W.E., "The Use of Standards and Prices for Protection of the Environment," *Swedish Journal of Economics* 73 (March 1971).

Brady, G.L. and Burris, C., "Report on Air Quality Management Agencies at the State and Local Level," President's Council on Environmental Quality, (National Technical Information Service, 1981).

_____, Bower, B.T., and Zayac, J.M., "Source Response to Regulatory Implementation Incentives in Air Quality Management," President's Council on Environmental Quality, (National Technical Information Service, 1981).

_____ and Bower, B.T., "The Effectiveness of Implementation Incentives in Air Quality Management in the United States," *International Comparisons of the Implementation Process in Environmental Regulation*, Hanf, K. and Downing, P., Editors (1981).

_____ and Cunningham, R., "The Economics of Pollution Control in the United States," *Ambio - Royal Swedish Academy of Sciences*, Vol. X, No. 4 (1981).

Brashares, E.N., Harrington, C.W., Magat, W.A., and Peskin, H.M., "Industrial Air and Water Pollution Regulations and Innovation," Report prepared for the Office of Technology Assessment (Washington, DC: Resources for the Future, 1979).

Buchanan, J. and Tullock, G., "Polluters' Profits and Political Response: Direct Controls Versus Taxes," *American Economic Review*, LXV, 1, (March 1975).

Comptroller General of the United States, "Improvements Needed in Controlling Major Air Pollution Sources" (Washington, DC: General Accounting Office, Rpt. No. CED - 78 - 165, (Jan. 2, 1979).

_____, "Air Quality: Do We Really Know What It Is?" (Washington, DC: General Accounting Office, Rpt. No. CED 79 - 84).

Dales, J.H., *Pollution, Property, and Prices*. (Univ. of Toronto Press, 1968).

DeLucia, R.J., An Evaluation of Marketable Effluent Permit Systems, U.S. Environmental Agency EPA-600/5-74-030, (Washington, DC: 1974).

Dames and Moore, "An Investigation of Prevention of Significant Deterioration (PSD) of Air Quality and Emission Offset Permitting Processes," Report to the National Commission on Air Quality (Washington, DC 1981).

Drayton, W., "Getting Smarter About Regulation," Harvard Business Review, (July/August, 1981).

Environment Reporter, October 16, 1981.

Environmental Protection Agency, "Controlled Trading Policy Statement: Guidance Concerning the Creation, Banking and Use of Discharge Reduction Credits," (June 17, 1981; revised November 19, 1981).

_____, "Controlled Trading: Technical Guidance Document" (November 19, 1981).

_____, "Concept Paper: Emission Reduction Banking and Trading Systems," OPA 113/0 (June 1980).

_____, Brokering Emission Reduction Credits: A Handbook, (1980).

Evans, J., "Opportunities for Innovation: Administration of Sections 111(j) and 113(d)(4) of the Clean Air Act and Industry's Development of Innovative Control Technology" (Washington, DC: Performance Development Institute, 1980).

Foskett, W.H., "Emission Offset Policy at Work: A Summary of Eight Cases," (Washington, DC: Performance Development Institute, 1979).

Friedlander, Anne F., Approaches in Controlling Air Pollution (Cambridge, MA: MIT Press, 1978).

Goklany, I.M., "Emission Inventory Errors for Point Sources and Some Quality Assurance Aspects," Journal of Air Pollution Control (April 1980).

Gordon, H.S., "The Economic Theory of a Common Property Resource: The Fishery," Journal of Political Economy (April 1954).

Kneese, A.V. and Schultze, C.L., Pollution, Prices and Public Policy (Washington, DC: The Brookings Institution, 1975).

Hahn, R.W., An Assessment of the Viability of Marketable Permits (Pasadena, CA: California Institute of Technology, 1981).

Lave, L.B. and Seskin, E.P., Air Pollution and Human Health (Baltimore, MD: Johns Hopkins University Press for Resources for the Future, 1977).

_____ and Omenn, G.S., Clearing the Air: Reforming the Clean Air Act (Washington, DC: The Brookings Institution, 1981).

Lederman, L. and Morrison, R.E., "Environmental and Worker Health/Safety Regulation and Technological Innovation," prepared for the International Conference on Regulation and Innovation, The Hague, Netherlands, June 1979.

Levin, Michael H., "Getting There: Implementing the Bubble' Policy" in Bardach, E. and Kagan, R.A., Social Regulation: Strategies for Reform (San Francisco, CA: Institute for Contemporary Studies, 1982).

Liroff, R.A., "Air Pollution Offsets: Trading, Selling, and Banking" (Washington, DC: The Conservation Foundation, 1980).

Mackintosh, D.R., "Air Pollution Offsets: Trading, Selling, and Banking" (Washington, DC: The Conservation Foundation, 1970).

McKenzie, R., Yandle, B. and Macauley, H., "The Economic Dimensions of Cotton Dust Standards for the Textile Industry: Three Essays," a working paper, Clemson University (1979).

Maloney, M.T. and McCormick, R.E., "Environmental Quality Regulation," a working paper, Clemson University (1980).

_____ and Yandle, B., "Bubbles and Efficiency: Cleaner Air at Lower Cost," Regulation, 4 (May/June 1980).

Montgomery, D.W., "Markets in Licenses and Efficient Pollution Control Programs," Journal of Economic Theory, 5, (1972).

_____, "Breaking Out of the Regulatory Dilemma: Alternatives to the Sterile Choice," Indiana Law Journal, 51, No. 3 (1976).

Morrison, R.E., "The Impact on Industrial Innovation of Environmental, Health, and Safety Regulations," prepared for the President's Domestic Policy Review on Industrial Innovation, March 1979.

National Commission on Air Quality, To Breathe Clean Air. (Washington,DC:1981).

National Academy of Sciences, Committee on Prevention of Significant Deterioration of Air Quality. On Prevention of Significant Deterioration of Air Quality. (Washington, DC: National Academy Press, 1981).

Noll, R.G., "The Feasibility of Marketable Permits in the United States," prepared for the Regulation Conference, International Institute of Management (Berlin, July 1981).

Quarles, J., Federal Regulation of New Industrial Plants (Washington, DC: Morgan, Lewis, and Bockius, 1979).

Roberts, M.J. and Spence, A.M., "Effluent Charges and Licenses Under Uncertainty," Journal of Public Economics, 5 (1976).

Teitenberg, T.H., "Transferable Discharge Permits and the Control of Stationary Source Air Pollution: A Survey and Synthesis," Land Economics, 56 (1980).

Urban Systems Research and Engineering, Inc., "An Institutional Assessment of the Implementation and Enforcement of the Clean Air Act, Buffalo Case Study," Report to the National Commission on Air Quality, AQ - 9130 (1980).

Vivian, W. and Hall, W., "An Empirical Examination of U.S. Market Trading in Air Pollution Offsets" (University of Michigan, Institute of Public Policy, 1981).

AN ECONOMIC-INCENTIVE APPROACH TO CONTROLLING ACID RAIN

HON. LES ASPIN

OF WISCONSIN

IN THE HOUSE OF REPRESENTATIVES

Friday, November 18, 1983

● Mr. ASPIN. Mr. Speaker, our efforts to meet the issue of acid rain cleared a major hurdle this past summer with the long-overdue admission by the administration that man-made pollutants are indeed to blame, and that we face a truly serious threat to our environment.

Now, it seems, we can all at least agree on the problem. That is supposed to be half the battle. But before we can win it, we must agree as well on a plan of attack. There is still considerable disagreement in that area, and with good reason.

I have introduced a bill (H.R. 4483) that I think offers a more effective approach to controlling acid rain than other legislation now ending. My bill would create an economic incentive for coal-burning electric utilities and other coal users to reduce sulfur emissions in whatever way they determined would cost them—and therefore their customers—the least.

The approach to acid rain that's the standard of comparison in the House is the Sikorski-Waxman bill (H.R. 3400), now under consideration by the Health and Environment Subcommittee of the Energy and Commerce Committee. The bill's sponsors claim it will cut acid-rain-related emissions 10 million tons annually by requiring the installation of smokestack scrubbers at the Nation's 50 dirtiest coal-fired powerplants. It would cover the cost of doing this with a tax on virtually all electric bills. The idea is to clean up the air without forcing plants to stop burning high-sulfur coal, and so to spare the jobs of a lot of coal miners.

Because I think controlling acid rain should be one of the Nation's first priorities, I have cosponsored the Sikorski-Waxman bill, but I have a number of problems with the approach it takes. Most important is its inflexibility. Instead of encouraging utility companies to find their most efficient ways of cutting down on sulfur dioxide emissions, the bill locks them all in to the same technology. The bill also fails to address the problem of emissions from powerplants yet to be built, or from nonutility sources. Finally, I am not sure it is fair to tax all electricity, regardless of whether its generation contributed to the acid rain problem. After all, some electricity is generated cleanly.

My bill takes a different tack. It has four basic components:

First, a tax of 50 cents per pound would be imposed on the sulfur content of coal sold after December 31, 1983. The tax would apply only to sulfur content in excess of a level that should not pose environmental problems. Companies who manage to get the sulfur out either before or after burning coal would get a rebate. Since the costs of scrubbing away sulfur as mandated in the Sikorski-Waxman bill are less than 50 cents per pound, my tax-rebate plan should spur a sulfur dioxide emission reduction of at least the 10 million pounds projected by Sikorski-Waxman.

Second, existing electric utilities that install equipment to control sulfur dioxide emissions would be reimbursed for 90 percent of their costs with revenues from the tax. This subsidy would double the incentive of the tax-rebate program.

Third, the tax would apply to nonutility combustion and, therefore, curtail emissions here, too. Such coal burners accounted for almost [illegible] percent of all sulfur dioxide emissions in 1980, and their share of responsibility for the problem is growing.

Fourth, my bill would curtail acid-rain-related emissions from all coal-fired plants—those in existence now as well as those to be built in the future.

The economic-incentive approach to pollution control is not a new idea. West Germany has had some success taking a similar tack in cleaning up the rivers of the Ruhr Basin. Yet, in America, despite our reliance on market principles, examples are rare. I think we should harness the control of acid rain to the doctrines of free enterprise.

Let me see if I anticipate and respond to some of the criticism my bill is likely to draw.

Some will no doubt say that it is too uncertain, that it does not guarantee results as the Sikorski-Waxman command approach claims to. It is true my bill does depend on the self-interested individual responses of the companies at which it is directed. But that is not necessarily bad. The command approach is basically arbitrary and encourages continued quibbling over its quantitative standards, instead of attention to the problem.

Others will speculate that electric utilities would pass along the tax to the consumer, rather than work to reduce emissions, avoid the tax and gain the subsidy. But sooner or later, that would cost them business, and even utilities like a brisk business. Furthermore, in this day of activist consumer groups and public service commissions, it is unlikely that utilities could get away with charging higher rates to cover an acid rain control tax when a lower cost alternative is available.

There is bound to be opposition to my economic-incentive plan from the high-sulfur coal producing States, where indeed a certain number of jobs would be lost as low sulfur coal became the fuel of choice. But, the bottom line is that more jobs would be gained in the mining and transport of low-sulfur coal than would be lost mining and transporting the high-sulfur variety. In many regions, the same people who lose their jobs mining high-sulfur coal could find new work mining low-sulfur coal without having to pull up stakes and move elsewhere. Still, on this issue, where you stand will depend on where you sleep. The things to keep in mind are that the net effect on employment from my bill is a plus and that the Sikorski-Waxman bill would spend nearly $60,000 a year of the consumer's money for every job it saved—more than $1 billion by 1995. For that kind of money, I think we need to look very closely at the alternative of finding spots in other industries for displaced high-sulfur coal miners. Sixty thousand dollars a head buys a lot of retraining.●

98TH CONGRESS
1ST SESSION

H. R. 4483

To amend the Internal Revenue Code of 1954 and the Clean Air Act to establish a program of tax incentives and financial assistance to reduce emissions of sulfur dioxide and related acid deposition.

IN THE HOUSE OF REPRESENTATIVES

NOVEMBER 18, 1983

Mr. ASPIN introduced the following bill; which was referred jointly to the Committees on Energy and Commerce and Ways and Means

---

A BILL

To amend the Internal Revenue Code of 1954 and the Clean Air Act to establish a program of tax incentives and financial assistance to reduce emissions of sulfur dioxide and related acid deposition.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SHORT TITLE

SECTION 1. This Act may be cited as the "Acid Deposition Control Act of 1983".

TITLE I—ACID DEPOSITION ASSISTANCE PROGRAM

SEC. 101. Title I of the Clean Air Act is amended by adding the following new part at the end thereof:

"PART E—ACID DEPOSITION CONTROL

"DEFINITIONS

"SEC. 181. As used in this part, the terms:

"(1) 'Commence' when used with respect to construction or modification has the same meaning as when used in section 111.

"(2) 'Fossil fuel fired electric utility generating plant' and 'electric utility' have the same meanings as provided in regulations under section 111.

"(3) 'Technological system of continuous emission reduction' has the meaning provided by section 111(a)(7).

"PAYMENT FOR CAPITAL COSTS OF CONTROL

"SEC. 182. (a) From the Fund established under this part, the Administrator shall make available to each owner or operator of a fossil fuel fired electric utility generating plant which—

"(1) is located within the contiguous 48 States, and

"(2) commences construction and installation of a technological system of continuous emission reduction for the control of emissions of sulfur dioxide after the date of the enactment of this part,

such sums as the Administrator deems necessary to pay for 90 per centum of the costs of the construction and installation of such system.

"(b) Payments under this section shall be made by the Administrator upon the Administrator's approval of an application from the owner or operator of the electric utility generating plant concerned. The Administrator shall approve any application if he determines that the payments under such application will be used for the construction or installation of a system referred to in subsection (a). Payments may be made according to such schedule as the Administrator deems appropriate. To the extent feasible such schedule shall correspond to the schedule of expenditures required to be made by the recipient for the construction or installation involved.

"(c) The Administrator, after consultation with the Secretary of the Treasury, shall promulgate regulations under which no payment may be made under this section for any costs unless the Administrator determines that, under applicable rates schedules, the full amount of such payment will be used to reduce those electric rate increases (payable by customers of the utility) which otherwise would result from the construction and installation concerned.

"PAYMENT FOR SULFUR REMOVED FROM EMISSIONS BEFORE DISPERSAL IN ATMOSPHERE

"SEC. 183. From the Fund established under this part, the Administrator shall pay to the operator of any facility which uses coal as a fuel for any purpose, 50 cents for each pound of sulfur which such operator certifies has been removed prior to the emission of the combustion products of such coal into the ambient air.

"(b) Any certification by any operator referred to in subsection (a) of the amount of sulfur contained in coal which such operator removed prior to the emission of the combustion products of such coal into the ambient air shall be made at such time and in such manner as the Administrator shall prescribe by regulation.

"(c) Any operator referred to in subsection (a) who misrepresents any material fact in any certification to the Administrator under this section shall be liable to the United States for a civil penalty in an amount not to exceed $10,000 for each such violation.

"ESTABLISHMENT OF FUND

"SEC. 184. (a) There is established in the Treasury of the United States a trust fund to be known as the 'Acid Deposition Control Fund' (hereinafter in this subpart referred to as the 'Fund'), consisting of such amounts as may be transferred to such Fund as provided in this section.

"(b) There are hereby credited, out of any money in the Treasury not otherwise appropriated, to the Fund amounts determined by the Secretary of the Treasury (hereinafter in this title referred to as the 'Secretary') to be equivalent to the amount received in the Treasury under the tax imposed by section 4122 of the Internal Revenue Code of 1954 (relating to additional tax on coal containing sulfur).

"(c) Amounts in the Fund shall be available only for purposes of making expenditures under this part. If amounts available in the Fund are inadequate to make all expenditures for which applications are received and approved under this part, the Administrator shall make such expenditures to the electric utilities in accordance with a priority list based upon the dates on which applications for assistance were approved by the Administrator.

"(d)(1) The amounts appropriated by subsection (b) shall be transferred at least monthly from the general fund of the Treasury to the Fund on the basis of estimates made by the Secretary of the amounts referred to in such subsection (b). Proper adjustments shall be made in the amount subsequently transferred to the extent prior estimates were in excess of or less than the amounts required to be transferred.

"(2)(A) The Secretary shall be the trustee of the Fund, and shall report to the Congress for each fiscal year ending on or after September 30, 1984, on the financial condition and the results of the operations of such Fund during such fiscal year and on its expected condition and operations during the next five fiscal years. Such report shall be printed as a House document of the session of the Congress to which the report is made.

"(B) It shall be the duty of the Secretary to invest such portion of such Fund as is not, in his judgment, required to meet current withdrawals. Such investments shall be in public debt securities with maturities suitable for the needs of such Fund and bearing interest at rates determined by the Secretary, taking into consideration current market yields on outstanding marketable obligations of the United States of comparable maturities. The income on such investments shall be credited to, and form a part of, such Fund.".

TITLE II—ACID DEPOSITION TAX

SEC. 201. (a) IN GENERAL.—Subchapter B of chapter 32 of the Internal Revenue Code of 1954 (relating to excise tax on coal) is amended by inserting after section 4121 the following new section:

"SEC. 4122. ADDITIONAL TAX ON COAL CONTAINING SULFUR.

"(a) TAX IMPOSED.—There is hereby imposed a tax on coal sold by the producer or importer equal to the amount per ton determined under subsection (b).

"(b) AMOUNT OF TAX.—The amount of the tax for any ton of coal shall be 50 cents for each pound of sulfur contained in such ton of coal to the extent the sulfur content of such ton exceeds 10 pounds of sulfur.

"(c) SPECIAL RULE; DEFINITION.—For purposes of this section—

"(1) DETERMINATION OF SULFUR CONTENT.—The sulfur content of any ton of coal shall be determined by multiplying 2,000 pounds by the average sulfur content per pound of such coal.

"(2) AVERAGE SULFUR CONTENT PER POUND.—The term 'average sulfur content per pound' means the percentage, by weight, of any pound of coal which is sulfur. Any sampling or analysis of coal to determine the average sulfur content of such coal shall be made in the manner prescribed by the Secretary in regulations.

"(d) COORDINATION WITH SECTION 4121.—The tax imposed by subsection (a) is in addition to the tax imposed by section 4121.

"(e) FRACTIONAL PART OF A TON.—In the case of a fraction of a ton of coal, the tax imposed by subsection (a) shall be the same fraction of the amount of such tax imposed on a ton of such coal."

(b) TECHNICAL AND CONFORMING AMENDMENTS.—

(1) Subsection (a) of section 4218 of such Code is amended by striking out the comma after "section 4121" and inserting in lieu thereof "or section 4122,".

(2) Subsection (a) of section 4221 of such Code is amended by inserting at the end thereof the following new sentence: "In the case of the tax imposed by section 4122, only paragraph (3) shall apply."

(3) Section 4293 of such Code is amended by striking out "and 4121" and inserting in lieu thereof ", 4121, and 4122".

(4)(A) Paragraph (2) of section 6416(b) of such Code is amended by adding at the end thereof the following new sentence: "Only subparagraph (A) shall apply in the case of any tax paid under section 4122."

(B) Paragraph (3) of such section 6416(b) is amended by inserting "or section 4122" after "section 4121".

(c) CLERICAL AMENDMENT.—The table of sections for subchapter B of chapter 32 of such Code is amended by inserting after the item relating to section 4121 the following new item:

"Sec. 4122. Additional tax on coal containing sulfur."

(d) EFFECTIVE DATE.—The amendments made by this section shall apply to coal sold or imported after December 31, 1983.

II

98TH CONGRESS
1ST SESSION

S. 2001

To amend the Clean Air Act to reduce interstate transport of pollutants, control acid deposition, and for other purposes.

IN THE SENATE OF THE UNITED STATES

OCTOBER 25 (legislative day, OCTOBER 24), 1983

Mr. DURENBERGER introduced the following bill; which was read twice and referred to the Committee on Environment and Public Works

---

A BILL

To amend the Clean Air Act to reduce interstate transport of pollutants, control acid deposition, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SHORT TITLE

SECTION 1. This Act may be cited as the "National Acid Deposition Reduction Act of 1983".

FINDINGS AND PURPOSES

SEC. 2. Congress finds that—

(a) acid deposition presents a threat to public health and the environment across large regions of the North American continent;

(b) the long-range transport of sulfur dioxide and nitrogen oxides and their transformation products contributes significantly to the acid deposition phenomenon;

(c) the principal source of acid compounds and their precursors in the atmosphere is the combustion of fossil fuels;

(d) oxides of nitrogen from mobile sources contribute to acid deposition in many parts of the Nation;

(e) reduction of total atmospheric loadings of sulfur dioxide and nitrogen oxides will mitigate the damage to affected ecosystems and enhance protection of public health and the environment;

(f) control strategies for pollutants that are precursors of acid deposition are well-known and economically feasible; and

(g) a nationwide tax system is necessary to provide funding for a portion of the costs of control strategies to lessen utility rate increases, avoid economic disruption and share the cost of control equitably among all sources contributing to the acid deposition phenomenon.

SEC. 3. The purposes of this Act are to—

(a) reduce sulfur dioxide emissions in the eastern United States by ten million tons by the year 1993;

(b) limit annual sulfur dioxide emissions in the United States to sixteen million six hundred thousand tons per year beginning January 1, 1993;

(c) establish an emissions fee on sulfur dioxide and nitrogen oxide emissions to finance capital investment in emissions control technology; and

(d) establish an assistance program within the Environmental Protection Agency to distribute funds from a trust fund so as to maximize emissions reductions per dollar invested and to protect sensitive areas and natural resources.

TITLE I—ACID DEPOSITION CONTROL PROGRAM

SEC. 4. Title I of the Clean Air Act is amended by adding the following new part at the end thereof:

"PART E—ACID DEPOSITION CONTROL

"DEFINITIONS

"SEC. 180. As used in this part, the terms—

"(a) 'acid deposition impact region' means the region consisting of the States of Alabama, Arkansas, Connecticut, Delaware, Florida, Georgia, Illinois, Indiana, Iowa, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, New Hampshire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, South

Carolina, Tennessee, Vermont, Virginia, West Virginia, Wisconsin, and the District of Columbia;

"(b) 'Act' means the Clean Air Act as amended including amendments made by the National Acid Deposition Reduction Act of 1983;

"(c) 'Administrator' means the Administrator of the Environmental Protection Agency;

"(d) 'continuous emissions reductions measures' means those control strategies described in section 111(a)(7) of the Act;

"(e) 'emissions rates' or 'actual emissions rates' means actual annual emissions per year stated in tons unless otherwise specified;

"(f) 'EPA region' means one of the ten administrative regions of the Environmental Protection Agency established pursuant to executive order;

"(g) 'major stationary source' has the same meaning provided in the Clean Air Act;

"(h) 'mobile source' has the same meaning provided in the Clean Air Act; and

"(i) 'sulfur dioxide' when used with respect to emissions means total sulfur emissions expressed as sulfur dioxide emissions.

"PURPOSES OF THIS PART

"SEC. 181. (a) There shall be achieved a reduction in annual emissions of sulfur dioxide in the acid deposition impact region of ten million tons from the total actual annual level of such emissions between January 1, 1980, and December 31, 1980. Such reduction shall be achieved pursuant to a phased reduction and completed no later than January 1, 1993.

"(b) Beginning January 1, 1993, the total actual annual level of emissions of sulfur dioxide from stationary sources shall not be allowed to exceed sixteen million six hundred thousand tons per year nationwide.

"(c) Not later than January 1, 1985, the Administrator shall publish an inventory and projection of sulfur dioxide and nitrogen oxide emissions for the United States which shall include the following information (in tons):

"(1) calendar year 1980 emissions of sulfur dioxide and nitrogen oxides from each major stationary source located within the fifty States by source and State;

"(2) calendar year 1980 emissions of nitrogen oxides from mobile sources for each of the fifty States by type of mobile source;

"(3) calendar year 1980 emissions of sulfur dioxide and nitrogen oxides from other than major stationary or mobile sources;

"(4) emissions of sulfur dioxide and nitrogen oxides from major stationary sources within the United States beginning operation after December 31, 1980, and before January 1, 1987;

"(5) additional increments of emissions of sulfur dioxide and nitrogen oxides above calendar year 1980 emissions rates for major stationary sources in operation on or before December 31, 1980;

"(6) additional increments of emissions of sulfur dioxide and nitrogen oxides from mobile sources and other than major stationary sources which are projected to occur after December 31, 1980, and before January 1, 1993;

"(7) additional increments of sulfur dioxide and nitrogen oxides emissions which will occur at major stationary sources as a result of increasing plant utilization above 1980 levels and which are not subject to the limitations of section 182 by reason of subsection (d) of that section; and

"(8) an estimate of the gross tons of reductions in annual emissions of sulfur dioxide that are necessary to achieve a net reduction of ten million tons from the actual annual emissions of sulfur dioxide in the acid deposition impact region in calendar year 1980.

"(d) The Administrator shall update the inventory and projection required by subsection (c) of this section on an annual basis.

"EMISSIONS CAP AND OFFSETS

"SEC. 182. (a) No major stationary source in operation before January 1, 1987, shall increase its actual rate of emissions of sulfur dioxide over that experienced by such source during the calendar year 1980, unless there has been identified for such source a simultaneous net reduction in emissions of such pollutant at one or more sources in the same EPA region in excess of the proposed increase in emission rate, and not otherwise required by a State implementation plan under section 110 of this Act or under section 183 or 185 of this part.

"(b) For each major stationary source beginning operations after January 1, 1987, there shall be identified for such source a simultaneous net reduction in emissions of sulfur dioxide at one or more sources in the same EPA region in excess of the proposed emission rate for that source, and not otherwise required by a State implementation plan under section 110 of the Act or under section 183 or 185 of this part.

"(c) For purposes of this section, a major stationary source beginning operation after January 1, 1987, and which commenced construction before January 1, 1984, shall be considered to be (i) in operation before January 1, 1987, and (ii) to have actual annual emissions not in excess of the standards of performance under section 111 of this Act.

"(d) For purposes of subsection (a) of this section, actual annual emissions may exceed emissions for calendar year 1980, if the additional increment of emissions results from increasing plant utilization above 1980 levels, but in no case may the actual annual emissions used to determine whether an increase has occured under subsection (a) exceed the rate of emissions that would result by multiplying the 1980 emissions rate by a plant utilization factor equal to the average level of production experienced by such source during the period from January 1, 1971, through December 31, 1980 (or the portion of such period during which such source was in operation), divided by the level of production experienced by such source in 1980.

"(e) Each State shall assure compliance with this section and the provision of emission reduction banks and brokerage institutions authorized under section 110 of the Act and section 183(b)(3) of this part.

"PRIORITY LIST AND EMISSIONS LIMITATIONS

"SEC. 183. (a) Not later than January 1, 1986, the Administrator shall publish a priority list of proposed control strategies for sulfur dioxide emissions reductions at major stationary sources which began operation prior to the enactment of this part, and for which the Administrator intends to provide assistance under section 184 of this Act.

"(b) For purposes of this section, control strategies for emissions reductions may include the following methods or projects for net emission reduction, in addition to continuous emission reductions measures under section 111(a)(7) of the Act, if emission limitations under such methods or projects are enforceable by the Federal Government, States other than those in which the emissions occur, or citizens under section 304 of the Act:

"(1) least emissions dispatching to meet electric generating demand at existing generating capacity;

"(2) retirement of major stationary sources at an earlier date than provided in schedules on file with the Federal Energy Regulatory Commission, the Internal Revenue Service, or State utility regulatory agencies;

"(3) trading of emissions reduction requirements and actual reductions on a State or regional basis, for which States and the Administrator are authorized to establish emission reduction banks or brokerage institutions, to facilitate such trading;

"(4) precombustion cleaning of fuels; and

"(5) fuel switching.

"(c) The priority list required by subsection (a) shall—

"(1) achieve a net reduction of ten million tons of sulfur dioxide emissions in the acid deposition impact region by January 1, 1993.

"(2) assign highest priority (subject to the provision of paragraph (3) of this subsection) to control strategies at sources which will achieve the greatest degree of emissions reduction for each dollar of assistance provided under section 184 of the Act;

"(3) reflect scientific knowledge concerning the relationship of emission sources to receptor areas, for areas or natural resources particularly sensitive to acid deposition, and to the extent possible health and environmental benefits of preserving and protecting those areas or natural resources; and

"(4) the Administrator may limit the number of projects on the priority list which rely all or in part on fuel switching, if he finds that substantial unemployment or economic dislocation might result should such limitation not be applied.

"(d) The Administrator may include on the priority list control strategies for emissions reductions by a source or group of sources located outside the acid deposition impact region upon a demonstration that such source, or group of sources, contributes to the deposition of acids or acid-forming compounds either within the acid deposition impact region or in other sensitive areas.

"(e) The Administrator may include on the priority list control strategies by a source, or a group of sources, located outside the acid deposition impact region which have as a primary purpose improvements in air quality other than reductions in sulfur dioxide emissions, if it can be demonstrated that such control strategy will substantially improve air quality by reducing pollutants in an air quality control region which is not in attainment with the standard for such pollutants, subject to the limitation that assistance for projects and methods to implement such control strategies does not exceed the authorization in section 184(d) of this part.

"(f) Not later than twelve months after publication of the priority list required by subsection (a) of this section, each State shall adopt enforceable measures to achieve the reductions in sulfur dioxide emissions set forth on the priority list for each source within such State including emissions limitations and schedules for compliance. The Governor of such State shall submit such measures to the Administrator for review in accordance with subsection (g) of this section, and to the Governors of all States in the acid deposition impact region for comment.

"(g) The Administrator shall approve within six months such measures submitted under subsection (f) of this section, if, taking into consideration the comments of Governors of the other States, the Administrator finds that such measures—

"(1) contain enforceable requirements for continuous emissions reductions;

"(2) contain requirements for monitoring by source and enforcement agencies to assure that limitations are being met; and

"(3) are adequate to achieve the reduction in sulfur dioxide emissions required by section 181 of the Act.

"(h) Each emissions limitation, schedule for compliance, or other measure adopted under this section shall be deemed a requirement of the State implementation plan approved or promulgated for such State under section 110 of this Act.

"(i) Not later than January 1, 1993, each major stationary source identified for a control strategy under this section shall be in compliance with an emission limitation established under this section. Nothing in this section shall require any such source to implement the particular control strategy for that source listed under subsection (a), provided that the emission limitation is achieved.

"USE OF THE FUND

"SEC. 184. (a) The Administrator shall use funds available under the trust fund established by title II of the National Acid Deposition Reduction Act of 1983 to pay up to 70 per centum of the capital costs necessary to implement the control strategies identified in the priority list required by section 183(a) of this part: *Provided,* That—

"(1) such payment shall be conditioned on the owner or operator of such source entering into an enforceable agreement with the Administrator to assure proper operation and maintenance of any technological system purchased with the assistance of funds under this section and compliance with emissions limitations established under section 183 of this part for the remaining life of such source; and

"(2) any assistance to a method or project described under section 183(b)(2) (early retirement) of this part be limited to technology for continuous emissions reductions as defined by section 111(a)(7) of this Act.

"(b) The Administrator shall use funds available under the trust fund established by title II of the National Acid Deposition Reduction Act of 1983 to pay up to 30 per centum of the operation and maintenance costs necessary to implement control strategies identified on the priority list required by section 183(a) of this part: *Provided*, That—

"(1) such payment shall be conditioned on the owner or operator of such source entering into an enforceable agreement with the Administrator to properly maintain and operate any technological system associated with such assistance and compliance with emissions limitations established under section 183 of this part for the remaining life of such source;

"(2) in the case of methods or projects described in section 183(b)(5) (fuel switching) the assistance is limited to 30 per centum of the difference in the delivered price of the fuels or fuel mixtures; and

"(3) in the case of methods or projects described in section 183(b)(1) (least emission dispatching) the assistance is limited to 30 per centum of the cost that could have been avoided through least cost dispatching.

"(c) Not later than twelve months after the publication of the priority list required by section 183(a), the Administrator shall enter into binding agreements with the owners and operators of all sources with a control strategy included on the priority list required by section 183(a) of this part. Such agreements shall include the provisions and conditions necessary to assure compliance with this part, including a plan and schedule of compliance for achieving emission limitations not later than January 1, 1993. The agreement shall include (1) enforceable requirements for continuous emission reductions; (2) requirements for monitoring by the source and enforcement agencies to assure that emission limitations are being met, and; (3) a schedule for emission reduction and achievement of the emissions limitation at the earliest practicable date, but no later than January 1, 1993. Owners and operators of sources with control strategies included on the priority list required by section 183(a) of this part may propose alternative methods or projects for assistance under this section, provided that such alternative control strategies achieve equivalent or greater emissions reductions for the same or lesser cost. Sources not in compliance with this subsection shall not be eligible for assistance under this part.

"(d) Not more than 5 per centum of the funds available under the trust fund established by title II of the National Acid Deposition Reduction Act of 1983 shall be used to assist projects described in section 183(e) of this part.

"(e) Up to 2 per centum of the funds available under the trust fund established by title II of the National Acid Deposition Reduction Act of 1983 may be used for the development and demonstration of sulfur dioxide emission control technologies or to conduct research authorized under title VII of the Energy Security Act of 1980.

"ALTERNATIVE REDUCTION REQUIREMENTS

"SEC. 185. (a) If the Administrator fails to publish the priority list required by section 183(a) of this part by January 1, 1986, then the provisions of subsection (c) of this section shall apply to all fossil-fuel-burning electric generating facilities which are major stationary sources located within the acid deposition on impact region.

"(b) If any State fails to promulgate emissions limitations and compliance schedules as required by section 183(f) of this part, then the provisions of subsection (c) of this section shall apply to all fossil-fuel-burning electric generating facilities which are major stationary sources located within such State.

"(c) The owner or operator of each fossil-fuel-burning electric generating facility which is a major stationary source which emitted at an annual rate equal to or greater than one and two-tenths pounds of sulfur dioxide per million British thermal units during 1980 shall comply with an emission limitation, or limitations for all such facilities owned or operated by the same entity, equivalent to an average among such facilities of one and two-tenths pounds of sulfur per million British thermal units on a thirty-day average. The owner or operator of each such facility shall submit to the Administrator a plan and schedule of compliance for achieving such emission limitation or equivalent emission reduction not later than one hundred eighty days after this subsection becomes effective for such source which provides for compliance not later than January 1, 1993. The Administrator shall approve such plan and schedule for compliance if it (1) contains enforceable requirements for continuous emission reductions, (2) contains requirements for monitoring by the source and enforcement agencies to assure that emission limitations are being met, and (3) will achieve the emission reduction required by this section at the earliest practicable date, but no later than January 1, 1993. Failure of such owner or operator to submit such approvable plan and schedule within one hundred eighty days after the effective date of this subsection, failure to comply with the plan and schedule for compliance, and failure to achieve the emission reduction required by this section at the earliest practicable date shall be a violation of emissions limitations for the purposes of sections 113, 120, and 304 of this Act.".

TITLE II—ACID DEPOSITION REDUCTION TRUST FUND

ESTABLISHMENT OF TRUST FUND

SEC. 5. (a) There is established in the Treasury of the United States a trust fund to be known as the Acid Deposition Reduction Trust Fund, consisting of such amounts as may be appropriated or transferred to such trust fund under this title.

(b) There are hereby appropriated, out of any money in the Treasury not otherwise appropriated, to the trust fund established by subsection (a) amounts determined by the Secretary of the Treasury to be equivalent to the revenues received in the Treasury under section 7 of this title.

TRUST FUND EXPENDITURES

SEC. 6. Amounts in the trust fund established under section 5 shall be available only for the purposes of making expenditures under section 184 of the Clean Air Act, as in effect on the date of enactment of this Act.

IMPOSITION OF TAXES

SEC. 7. (a) There is hereby imposed a tax on—

(1) emissions of sulfur dioxide from major stationary sources (as defined under section 302(j) of the Clean Air Act) in the United States;

(2) emissions of oxides of nitrogen from major stationary sources (as defined under section 302(j) of the Clean Air Act) in the United States; and

(3) emissions of oxides of nitrogen from motor vehicles (as defined under section 216(2) of the Clean Air Act) and other mobile sources of such emissions. For purposes of this part a mobile source includes aircraft, railroad locomotives, and heavy construction equipment, without regard to whether it is capable of being relocated.

(b) The tax imposed by subsection (a) shall take effect on January 1, 1985, and shall terminate December 31, 1994.

(c) The Secretary of the Treasury, after consultation with the Administrator of the Environmental Protection Agency, shall establish the rates of the tax imposed by subsection (a) such that in the judgment of the Secretary the total amount received due to such tax during the period from January 1, 1985, through December 31, 1994, shall be $40,000,000,000. Such rates shall be established so that—

(1) two-thirds of such amount will be received from the tax imposed under subsection (a)(1);

(2) one-sixth of such amount will be received from the tax imposed under subsection (a)(2); and

(3) one-sixth of such amount will be received from the tax imposed under subsection (a)(3).

(d)(1) The tax imposed under subsections (a)(1) and (a)(2) shall be paid by the operator of each major stationary source of such emissions.

(2) The portion of the tax imposed under subsection (a)(3) attributable to light-duty motor vehicles (as defined under section 202(b)(3)(B) of the Clean Air Act) shall be paid at the time of first sale by the ultimate purchaser (as defined under section 216(5) of the Clean Air Act) of each such light-duty motor vehicle sold in the United States after December 31, 1984.

(3) The portion of the tax imposed under subsection (a)(3) attributable to mobile sources other than light-duty motor vehicles (as defined under section 202(b)(3)(B) of the Clean Air Act) shall be paid by the owner of each such mobile source on an annual basis.

(e)(1) The Secretary of the Treasury is authorized to adjust the rate established under subsection (c) to better comply with the requirements of such subsection in the light of accumulated experience. Such adjustments as the Secretary determines appropriate shall take effect on January 1, 1987, January 1, 1990, or January 1, 1993.

(2) The Secretary of the Treasury is authorized to modify the rate established under subsection (c) with respect to the operator of a specific fossil-fuel-burning electric generating facility which will be installing a technological system of continuous emission reduction to comply with an emission limitation under section 110 or 183 of the Clean Air Act during the period such tax will be in effect. Such modification shall establish a tax of equal annual amounts during such period, based on the average of emission levels expected prior to and subsequent to the installation and operation of such technological system.

(3) The Secretary of the Treasury is authorized to establish the rate of the tax imposed under subsections (a)(1) and (a)(2) on the basis of ranges of quantities of sulfur dioxide

or oxides of nitrogen emitted from a class of major stationary sources, in lieu of a strict per-unit-of-weight rate, if it is enforceable and produces adequate revenue, without imposing monitoring costs which bear no reasonable relationship to the revenues received from such sources.

ADMINISTRATIVE PROVISIONS

SEC. 8. (a) The amounts appropriated by section 5(b) shall be transferred at least monthly from the general fund of the Treasury to the trust fund established by section 5(a) on the basis of estimates made by the Secretary of such amounts. Proper adjustments shall be made in the amount subsequently transferred to the extent prior estimates were in excess of or less than the amounts required to be transferred.

(b) It shall be the duty of the Secretary of the Treasury to invest such portion of the trust fund established by section 5(a) as is not, in the judgment of the Administrator of the Environmental Protection Agency, required to meet current obligations. Such investments shall be in public debt securities with maturities suitable for the needs of such trust fund and bearing interest at rates determined by the Secretary, taking into consideration current market yields on outstanding marketable obligations of the United States of comparable maturities. The income on such investments shall be credited to and form a part of such trust fund.

(c) There are authorized to be appropriated to the trust fund established by section 5(a), out of any money in the general fund of the Treasury not otherwise appropriated, as repayable advances such sums as may be necessary to carry out the purposes of such trust fund during the period when the amounts received in such trust fund are less than expected due to a modification in tax rate under section 7(e)(2). Advances made pursuant to this subsection shall be repaid, and interest on such advances shall be paid, to the general fund of the Treasury when the Secretary determines that moneys are available for such purposes in the trust fund to which the advance was made. Such interest shall be at rates computed in the same manner as provided in subsection (b) and shall be compounded annually.

(d) The Secretary may allow a source to make annual payments of equal amounts in those cases where a source otherwise would be required, prior to installation of control technology to make payments substantially greater than payments after the installation of such technology. In those cases where such a source is one which would receive assistance from the trust fund, such source may escrow its tax payments if such action would levelize electricity rate charges.

98TH CONGRESS
1ST SESSION

H. R. 3400

To amend the Clean Air Act to control certain sources of sulfur dioxides and nitrogen oxides to reduce acid deposition and for other purposes.

IN THE HOUSE OF REPRESENTATIVES

JUNE 23, 1983

Mr. SIKORSKI (for himself, Mr. WAXMAN, and Mr. GREGG) introduced the following bill; which was referred to the Committee on Energy and Commerce

---

A BILL

To amend the Clean Air Act to control certain sources of sulfur dioxides and nitrogen oxides to reduce acid deposition and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SHORT TITLE

SECTION 1. This Act may be cited as the "National Acid Deposition Control Act of 1983".

FINDINGS AND PURPOSES

SEC 2. (a) The Congress finds that—

(1) The long-range transport of sulfur dioxides and nitrogen oxides and their transformation products is an interstate, national, and international problem.

(2) The deposition of acid compounds from the atmosphere is causing and contributing to widespread long-term ecosystem degradation in many parts of the Nation.

(3) The problem of acid deposition is nationwide in scope and of national and international significance and cannot be addressed adequately without Federal intervention.

(4) Current levels of emissions of sulfur dioxides and nitrogen oxides from existing sources as well as increased emissions from new sources present a threat to public health and welfare and the environment in States and countries other than those in which the air pollutants are emitted.

(5) The principal source of the acid compounds in the atmosphere and their precursors is the combustion of fossil fuels.

(6) Oxides of nitrogen from mobile sources causes and contributes to acid deposition in many parts of the Nation.

(7) Reduction of the total atmospheric loading of sulfur dioxides and nitrogen oxides will mitigate the

damage to affected ecosystems and enhance protection of public health and welfare and the environment.

(8) More effective regulation of the intrastate and interstate transport of sulfur dioxides and nitrogen oxides is needed in order to protect the health and welfare of citizens of affected States and the economic growth opportunities of affected States.

(9) Control strategies and technology for precursors to acid deposition exist now that are economically feasible.

(10) Current and future generations of Americans will be adversely affected by delayed action, so that efforts to remedy the problem should commence now.

(11) The installation of additional control technology for a number of existing electric utility plants would provide an effective and verifiable means to reduce emissions of sulfur dioxides; and

(12) A nationwide fee system is necessary to provide funding for a portion of the capital cost of the required technology so as to lessen utility rate increases and avoid economic disruption or increased unemployment.

(b) The purposes of this Act are—

(1) to initiate a program to protect health and welfare and the environment from any actual or poten-

tial adverse effect caused by ambient concentrations and deposition of sulfur dioxides and nitrogen oxides and the products of atmospheric transformation of these air pollutants;

(2) to enhance the ability of States to protect the public health and welfare and the environment of their citizens from air pollution originating in other States;

(3) to ensure that current employment will not be jeopardized as a result of the effort to control acid deposition; and

(4) to spread the costs of controlling acid deposition so that no region of the Nation bears an unfair burden.

TITLE I—ACID DEPOSITION CONTROL AND ASSISTANCE PROGRAM

SEC. 101. Title I of the Clean Air Act is amended by adding the following new part at the end thereof:

"PART E—ACID DEPOSITION CONTROL

"PURPOSE OF PART

"SEC. 181. (a) The purpose of this part is to decrease sulfur dioxide emissions in the 48 contiguous States by requiring certain electric utility plants and other sources to reduce, by 1993, their rates of sulfur dioxide emissions to rates which (if achieved by those sources in 1980) would have resulted in total emissions from such sources

10,000,000 tons below the actual total of sulfur dioxide which those sources emitted in 1980. Such reduction shall be achieved through—

"(1) a program under subpart 1 consisting of direct federally mandated emission limitations for 50 of the largest emitters of sulfur dioxide; and

"(2) a program under subpart 2 consisting of State plans to provide for such reductions in the emission rates of other existing sources as may be necessary to achieve the remaining portion of such 10,000,000 ton reduction.

Ninety percent of the capital costs of continuous emission control technology used for the purpose of such programs shall be funded through a fee on the generation of electric energy as provided in subpart 3.

"(b)(1) Nothing in this part shall be construed to limit emissions from any new (or modified) electric utility unit, to limit emissions from any other new source of sulfur dioxide, or to limit emissions from any oil or gas fired electric utility unit or other source which changes the fuel which such unit or plant used in 1980.

"(2) Nothing in this part shall be construed to prevent any existing electric utility plant or any other existing stationary source of sulfur dioxide from at any time increasing plant utilization above 1980 levels.

"(3) Nothing in this part shall be construed to require any State to reduce emissions under subpart 2 of this part to take into account emissions increases attributable to units or sources referred to in paragraphs (1) and (2).

"DEFINITIONS

"SEC. 182. As used in this part, the terms:

"(1) 'New' and 'modified' when used with respect to an electric utility unit or other source means an electric utility unit or other source which commenced construction (or modification) after December 31, 1980, and which is subject to new source performance standards under section 111.

"(2) 'Commenced' when used with respect to construction or modification has the same meaning as when used in section 111.

"(3) 'Fossil fuel fired electric utility generating plant' means all of the fossil fuel fired electric utility steam generating units owned or operated by an electric utility which are located on one or more contiguous or adjacent properties.

"(4) 'Steam generating unit', 'electric utility', and 'fossil fuel' have the same meanings as provided in regulations under section 111 applicable to electric utility steam generating units for which construction is commenced after September 18, 1978 (40 CFR 60.41a).

"(5) 'Btu' means a British thermal unit.

"(6) 'Technological system of continuous emission reduction has the meaning provided by section 111(a)(7).

"(7) 'Sulfur dioxide' when used with respect to emissions means total sulfur emissions expressed as sulfur dioxide emissions.

"RELATIONSHIP TO OTHER REQUIREMENTS

"SEC. 183. Nothing in this part shall be construed to affect or impair the requirements of section 110 (or of any applicable implementation plan) or of any other section of this Act, except that any stationary source which is subject to any such requirements may also be subject to additional requirements under this part.

"Subpart 1—Retrofit Technology for 50 Facilities

"FEDERALLY MANDATED EMISSION REDUCTIONS

"SEC. 185. (a)(1) The Administrator shall identify each fossil fuel fired electric utility generating plant which emitted sulfur dioxide during the calendar year 1980 at an annual average rate equal to or in excess of 3 pounds per million Btu.

"(2) Not later than 2 months after the date of the enactment of this part, the Administrator shall publish in the Federal Register a list of the 50 plants among those identified under paragraph (1) which have the largest total emissions of sulfur dioxide during the calendar year 1980 and shall notify the owner or operator of each plant on such list.

"(3) Not later than 4 months after such date of enactment, and after notice and opportunity for comment, the Administrator shall promulgate, and publish in the Federal Register, a final list of the 50 plants among those identified under paragraph (1) which the Administrator determines had the largest total emissions of sulfur dioxide during the calendar year 1980.

"(b)(1) Not later than January 1, 1985, the owner or operator of each plant listed under subsection (a)(3) shall submit to the Administrator a compliance schedule under this section, including increments of progress. Within 1 year after the submission of a compliance schedule, and after notice and opportunity for hearing, the Administrator shall approve or disapprove the schedule.

"(2) If a compliance schedule is not submitted on or before the date required under paragraph (1) for any plant listed under subsection (a)(3), if a schedule submitted under paragraph (1) for such plant is not approved by the Administrator before January 1, 1986, the Administrator shall promulgate a compliance schedule, including increments of progress, for such plant on January 1, 1986. If, after January 1, 1986, the Administrator determines that any previously approved compliance schedule, including the increments of progress in such schedule, is inadequate to meet the requirements of subsection (c), the Administrator shall require submission of, or promulgate, a modified compliance schedule, including increments of progress, for such plant. Each schedule which is approved or promulgated by the Administrator under this subsection shall be published in the Federal Register.

"(c)(1) Each compliance schedule under this section shall provide that—

"(A) a technological system of continuous emission reduction shall be used for each steam generating unit in the fossil fuel fired electric utility generating plant concerned, and

"(B) sulfur dioxide emissions from such plant for the calendar year 1990 and for each calendar year thereafter shall not exceed—

"(i) 1.2 pounds per million Btu heat input and 10 percent of the total annual sulfur dioxide emissions during the calendar 1980 (90 percent reduction), or

"(ii) 0.6 pounds per million Btu and 30 percent of the total annual sulfur dioxide emissions during the calendar 1980 (70 percent reduction).

Compliance by the plant with such emission limitation shall be determined in the same manner as provided for determination of compliance with regulations under section 111 applicable to electric utility steam generating units for which construction is commenced after September 18, 1978, except that (I) such regulations shall be applied on a plantwide basis (including all fossil fuel fired electric utility units which comprise the plant) and (II) compliance with the 1.2 pounds per million Btu and 0.6 pound per million Btu rates set forth in clauses (i) and (ii) shall be determined on the basis of average annual emissions of the plant in lieu of the 30-day rolling average which is applicable to each steam generating unit under such regulations.

"(2) The compliance schedule under this subsection shall provide that—

"(A) contracts shall be entered into for the purchase and installation of the technological systems of continuous emission reduction not later than January 1, 1988;

"(B) such systems shall be installed and in operation not later than January 1, 1990; and

"(C) the emission limitation required under paragraph (1) shall be achieved for each calendar year after 1989.

"(d) For purposes of sections 113, 114, 116, 120, and 304 of this Act, a compliance schedule under this section (including any increment of progress set forth in such schedule) shall be treated as an emission limitation.

"PAYMENT FOR CAPITAL COSTS OF CONTROL

"SEC. 186. (a) From the fund established under subpart 3 of this part, the Administrator shall make available to each owner or operator of a plant which is subject to a compliance schedule under section 185 such sums as the Administrator deems necessary to pay for 90 percent of the costs of the construction and installation of the technological system of continuous emission reduction necessary to comply with the emission limitation applicable under section 185(c)(1).

"(b) The Administrator, after consultation with the Secretary of the Treasury, shall promulgate regulations under which—

"(1) no payment may be made under this section to a utility for any costs unless the Administrator determines that, under applicable rates schedules, the full amount of such payment will be used to reduce those electric rate increases (payable by customers of the utility) which otherwise would result from the construction and installation concerned; and

"(2) such payments shall be made at such times as will minimize any electric rate increases for customers of the utility.

"Subpart 2—State Plans for Additional Emission Reductions

"CALCULATION OF STATE SHARES

"SEC. 191. (a) Not later than 4 months after the date of the enactment of this part, for each of the 48 contiguous States, the Administrator shall compute a State share of the 10,000,000 ton reduction in annual emissions of sulfur dioxide referred to in section 181(a).

"(b) The State share for each such State shall be a percentage of 10,000,000 tons determined by dividing the amount computed under paragraph (1) by the amount computed under paragraph (2).

"(1) The Administrator shall compute the total annual emissions of sulfur dioxide during the calendar year 1980 from fossil fuel fired electric generating plants which are located in the State and which, during the calendar year 1980, emitted sulfur dioxide at an annual average rate in excess of 1.2 pounds per million Btu.

"(2) The Administrator shall compute the total annual emissions of sulfur dioxide during the calendar year 1980 from all fossil fuel fired electric generating plants which are located in the 48 contiguous States and which, during the calendar year 1980, emitted sulfur dioxide at an annual average rate in excess of 1.2 pounds per million Btu.

"(c) The Governors of any two or more States may (by agreement) reallot among agreeing States the State share of two or more agreeing States if, under such reallotment, the total reduction in annual emissions of sulfur dioxide from all stationary sources subject to emission limitations under section 193(a) is equal to or greater than the total reduction in annual emissions of sulfur dioxide from such sources which would be required under this part in the absence of such reallotment.

"SUBMISSION AND APPROVAL OF STATE PLANS

"SEC. 192. (a) On or before June 1, 1985, each State for which a State share is calculated under section 191 shall submit a plan to the Administrator under this section.

"(b) Within 6 months from the date of submission of a State plan under this section, the Administrator shall approve the plan if he determines that the plan contains provisions, including enforceable increments of progress, adequate to assure that the emission limitations required under section 193 will be achieved by January 1, 1993.

"(c) If a State plan is submitted under this section on or before June 1, 1985, and the Administrator disapproves such plan, the Administrator shall notify the State of the reasons for such disapproval and the State may resubmit such plan within 6 months from the date on which such notice is provided. If no State plan has been submitted under this section on or before June 1, 1985, or if no State plan has been approved by the Administrator on or before January 1, 1988, the Administrator shall promulgate a State plan under this section for such State on January 1, 1988.

"EMISSION LIMITATIONS IN STATE PLANS

"SEC. 193. (a) The plan for each State required to submit a plan under section 192 shall provide for emission limitations applicable to any stationary sources in the State for which the actual annual sulfur dioxide emission rates have been calculated by the Administrator for the calendar year 1980, other than a source which is one of the 50 electric utility plants subject to subpart 1 of this part. The emission limitations for each stationary source subject to the State plan shall establish an allowable average annual sulfur dioxide emission rate for the source. The allowable average annual sulfur dioxide emission rates for such sources shall be established at such levels that—

"(1) if each source emitted sulfur dioxide at the allowable rate during the calendar year 1980, and

"(2) a credit is applied in accordance with subsection (b), the total reduction in actual annual emissions of sulfur dioxide in the State during the calendar year 1980 would equal the State share determined under section 191.

"(b) A credit under this subsection shall be applied under subsection (a)(2) for each State in which there is located one of the 50 electric utility plants subject to subpart 1 of this part. The credit shall be equal to the total annual reduction in emissions of sulfur dioxide which would have been achieved in that State during the calendar year 1980 if the plants in that State which are subject to subpart 1 were each in compliance with the emission limitations under subpart 1 during the calendar year 1980.

"(c) The State plans under this subsection may provide for compliance with the emission limitations applicable under such plans through the use of a technological system of continuous emission reduction or any other requirements which the State deems appropriate to reduce the sulfur dioxide emission rate of any stationary sources for which the actual annual sulfur dioxide emission rates have been calculated by the Administrator for the calendar year 1980 (other than an electric utility plant subject to subpart 1 of this part).

"(d) Each requirement of a State plan approved or promulgated by the Administrator under this section shall be treated, for purposes of sections 113, 114, 116, 120, and 304 as a requirement of an applicable implementation plan.

"FINANCIAL ASSISTANCE FOR COMPLIANCE WITH STATE PLANS

"SEC. 194. From the fund established under subpart 3 of this part, the Administrator shall make available to each owner or operator of an electric utility generating plant which is subject to requirements under a State plan approved or promulgated under this part such sums as the Administrator deems necessary to pay for 90 percent of the costs of the construction and installation of any technological system of continuous emission reduction (as defined in section 111(a)(7)) which is necessary to comply with such requirements. Payments under this section shall be subject to the regulations under section 186(b).

"Subpart 3—Acid Deposition Control Fund

"ESTABLISHMENT OF FUND

"SEC. 195. (a) There is established in the Treasury of the United States a trust fund to be known as the 'Acid Deposition Control Fund' (hereinafter in this subpart referred to as the "Fund"), consisting of such amounts as may be transferred to such Fund as provided in this section.

"(b) There are hereby credited, out of any money in the Treasury not otherwise appropriated, to the Fund amounts determined by the Secretary of the Treasury (hereinafter in this title referred to as the 'Secretary') to be equivalent to the amount received in the Treasury under section 196.

"(c) Amounts in the Fund shall be available only for purposes of making expenditures which are described in subpart 1 and subpart 2 of this part. If amounts available in the fund are inadequate to make all expenditures which are required to be made by the Administrator under such subparts, the Administrator shall make such expenditures in accordance with the following priorities:

"(1) The Administrator shall first make expenditures required under section 186 and, if amounts in the fund are inadequate to make all expenditures required under such section 186, the available amounts shall be allocated first to the facilities which first applied for payment under such section 186.

"(2) The Administrator shall next make expenditures required under section 194 and, if amounts in the fund are inadequate to make all expenditures required under such section 194, the available amounts shall be allocated first to the facilities which first applied for payment under such section 184.

"(d)(1) The amounts appropriated by subsection (b) shall be transferred at least monthly from the general fund of the Treasury to the Fund on the basis of estimates made by the Secretary of the amounts referred to in such subsection (b). Proper adjustments shall be made in the amount subsequently transferred to the extent prior estimates were in excess of or less than the amounts required to be transferred.

"(2)(A) The Secretary shall be the trustee of the Fund, and shall report to the Congress for each fiscal year ending on or after September 30, 1984, on the financial condition and the results of the operations of such Fund during such fiscal year and on its expected condition and operations during the next 5 fiscal years. Such report shall be printed as a House document of the session of the Congress to which the report is made.

"(B) It shall be the duty of the Secretary to invest such portion of such Fund as is not, in his judgment, required to meet current withdrawals. Such investments shall be in public debt securities with maturities suitable for the needs of such Fund and bearing interest at rates determined by the Secretary, taking into consideration current market yields on outstanding marketable obligations of the United States of comparable maturities. The income on such investments shall be credited to, and form a part of, such Fund.

"FEES

"SEC. 196. (a) Under regulations promulgated by the Administrator, there shall be imposed a fee of 1 mill for each kilowatt hour of electric energy generated in the contiguous 48 States by an electric utility and 1 mill for each kilowatt hour of electric energy imported into the contiguous 48

States. The fee shall not apply with respect to electric energy which is—

"(1) used at the electric generating facility concerned, or

"(2) generated by a nuclear generating facility.

The fee shall take effect with respect to electric energy generated, or imported, after December 31, 1984. The fee shall cease to apply on the earlier of—

"(1) December 31, 1995, or

"(2) the date on which all payments required to be made under subparts 1 and 2 of this part have been made.

The Administrator may terminate the fee at an earlier date if, under estimates made by the Administrator, sufficient funds have been collected to fund 100 percent of the payments which are to be made under subparts 1 and 2 of this part.

"(b) The regulations of the Administrator under subsection (a) shall be promulgated not later than 6 months after the date of the enactment of this part and shall set forth the time and manner required for payment of the fee imposed under subsection (a) and the information required to be reported in connection with the payment of such fee.

"(c)(1) Any electric utility (or importer of electric energy) which fails or refuses to pay any amount of a fee imposed under subsection (a) or which fails or refuses to file any report or other document required by the Administrator in connection with the imposition of such fee shall, in addition to liability for any unpaid amount of such fee (and interest on any such unpaid amount), be liable for a civil penalty of $50,000 for each day during which such failure or refusal continues. Any person who makes any false or misleading statement in any such report or other document required by the Administrator in connection with the imposition of such fee shall be liable for a civil penalty of $50,000.

"(2) The Administrator shall bring a civil action against any electric utility (or importer) which fails or refuses to pay any amount of a fee imposed under subsection (a), fails or refuses to file any report or other document required by the Administrator in connection with the imposition of such fee, or makes any false or misleading statement in any such report or other document required by the Administrator in connection with the imposition of such fee. Civil actions under this subsection shall be brought in the same manner and in accordance with the same procedures as are applicable to civil actions brought under section 113(b) against any person who violates any requirement of an applicable implementation plan.

"(d) Any electric utility (or importer of electric energy) which knowingly fails or refuses to pay any amount of a fee imposed under subsection (a) or which knowingly fails or refuses to file any report or other document required by the Administrator in connection with the imposition of such fee shall, in addition to civil liability under subsection (c), be subject to a criminal penalty of $100,000.".

CONFORMING AMENDMENTS

SEC. 102. (a) Section 113(a)(3) of the Clean Air Act is amended by inserting "or is in violation of any requirement in effect pursuant to subpart 1 of part E," after "inspections, etc.)".

(b) Section 113(b) of the Clean Air Act is amended by inserting the following immediately after paragraph (5): "Whenever any person violates any requirement in effect pursuant to subpart 1 of part E, the Administrator may commence a civil action for permanent or temporary injunction or to assess and recover a civil penalty of not more than $25,000 per day of violation, or both.".

(c) Section 113(c)(1)(C) of the Clean Air Act is amended by inserting "or violates any requirement in effect pursuant to subpart 1 of part E," before "or".

(d) Section 307(b)(1) of the Clean Air Act is amended by inserting ", any final action taken by the Administrator under part E of title I" after "120" in the first sentence thereof.

TITLE II—CONTROL OF NITROGEN OXIDE EMISSIONS

REVISIONS OF NEW SOURCE PERFORMANCE STANDARD

SEC. 201. Section 111 of the Clean Air Act is amended by adding the following new subsection at the end thereof:

"(k) The Administrator shall revise the standards of performance for emissions of nitrogen oxides from electric utility steam generating units which burn bituminous or subbituminous coal. Such revised standards shall prohibit the emission of nitrogen oxides from such units at a rate which exceeds—

"(1) 0.30 pounds per million Btu's, in the case of subbituminous coal; and

"(2) 0.40 pounds per million Btu's, in the case of bituminous coal

based on a 30-day rolling average. Such revised standard shall take effect with respect to units which commence construction after the date of the enactment of this subsection. As used in this subsection, the terms 'electric utility steam generating unit', 'bituminous coal', and 'subbituminous coal' have the same meanings as when used in 40 C.F.R. part 60, subpart Da, as in effect on January 1, 1983.".

EMISSIONS FROM MOBILE SOURCES

SEC. 202. (a) Section 202 of the Clean Air Act is amended by adding the following new subsection at the end thereof:

"(g) Effective with respect to vehicles and engines manufactured during and after the model year 1986, the regulations under subsection (a) applicable to emissions of oxides of nitrogen from trucks and truck engines the gross vehicle weight of which does not exceed 8,500 pounds shall contain standards which provide that such emissions may not exceed the number of grams per vehicle mile specified in the following table:

Gross Vehicle Weight	**Emission Standard**
Not in excess of 6,000 lbs	1.2
In excess of 6,000 lbs	1.7

Effective with respect to vehicles and engines manufactured during and after the model year 1986, the regulations under subsection (a) applicable to emissions of oxides of nitrogen from trucks and truck engines the gross vehicle weight of which exceeds 8,500 pounds shall contain standards which provide that such emissions may not exceed 4.0 grams per brake horsepower-hour. Nothing in subparagraph (B) or (E) of subsection (a)(3) shall apply to any standard established under this subsection.".

(b) Section 202(a)(3)(A)(ii) is amended by inserting "and except as otherwise provided in subsection (g)," after "(E)".

Technologies and Management Strategies for Hazardous Waste Control

CONGRESS OF THE UNITED STATES
Office of Technology Assessment
Washington, D.C. 20510

CHAPTER 1

Summary

Overview

Newly established Federal regulations for hazardous waste management facilities may not effectively detect, prevent, or control hazardous releases, especially over the longer term. Moreover, some regulatory standards and controls will be set by State authorities, who may not have the resources to make technically complex decisions. **Consistent levels of protection nationwide are not assured.**

In less than a decade the Federal program has advanced State efforts, cleaned up some uncontrolled sites, and assisted industry in improving its waste management. **Nevertheless, data inadequacies conceal the scope and intensity of hazardous waste problems, especially those related to health and environmental effects, and impede effective regulation of wastes and waste management facilities.**

About 255 million to 275 million metric tons (tonnes) of hazardous waste under Federal and State regulation are generated annually. Some States have stricter definitions for hazardous waste than the Federal program, which regulates about 40 million tonnes annually. **Millions of tonnes of federally exempted hazardous waste disposed in sanitary landfills pose substantial risks.** Such exemptions cover most hazardous waste from generators producing less than 1 tonne a month. In addition, large volumes of relatively low-hazard waste such as mining waste and waste generated by the burning of fossil fuels are exempt from Federal regulation.

Land disposal is used for as much as 80 percent of regulated hazardous waste, some of which may remain hazardous for years or centuries. **Inappropriate disposal of hazardous waste on land creates the risk of contaminating the environment, particularly ground water, which could cause adverse health effects.** Federal policies may inadvertently reduce private costs of land disposal by shifting some long-term cleanup and monitoring costs to Government or to society as a whole; the effect may be to retard the adoption of alternatives such as waste reduction and waste treatment. **A key policy issue is: Can unnecessary risks and future cleanup costs be eliminated by limiting the use of land disposal and by making alternatives to it more attractive?**

As their responsibilities mount, States fear reductions in Federal support and seek a stronger policy role. States sometimes cannot raise even the required minimum 10 percent of initial Superfund cleanup costs—and they must assume all future operation and maintenance costs. **Because there are no specific Federal technical standards for the extent of cleanup, and because there is an incentive to minimize initial costs, remedial actions may be taken that will prove ineffective in the long term. When Superfund expires in 1985, many uncontrolled sites still will require attention.**

Actions that enhance public confidence in the equity, effectiveness, and vigorous enforcement of Government programs may reduce public opposition to siting hazardous waste facilities. Opposition also may be reduced by improvement in the dissemination of accurate technical information on issues such as waste treatment alternatives to land disposal.

Five policy options are examined:

1. **Continue with the current program.**
2. **Extend Federal controls** to more hazardous waste, and establish national regulatory standards based on specific technical criteria. Also, restrict disposal of high-hazard waste on land, and improve procedures for permitting facilities and delisting waste.
3. **Establish Federal fees on waste generators as an economic incentive to reduce the generation of waste and discour-**

age land disposal; impose higher fees on generators of high-hazard waste that are land disposed: provide assistance for capital investments and research and development (R&D) for waste reduction and waste treatment.

4. Study the costs and advantages of **classifying wastes and waste management facilities by degree-of-hazard** to match hazards and risks with levels of regulatory control.
5. Examine the need for greater **integration of Federal environmental programs** to remove gaps, overlaps, and inconsistencies in the regulation of hazardous waste, and to make better use of technical data and personnel.

Substantial Risks and Damages

Uncontrolled and careless disposal of industrial waste became a national concern in the mid and late 1970's. It became evident at many waste sites that mismanagement and indiscriminate dumping of waste were causing harmful substances to be released into the land, water, and air. Waste handlers and the general public alike were threatened with direct exposure to hazardous waste.

It also became increasingly clear that even well-intentioned and presently accepted waste management practices, particularly the use of landfills, surface impoundments, and lagoons, might still constitute substantial threats. These threats arise from the potential slow leakage of waste constituents or leachate* through the soil and into ground water, which is a source of drinking water for many communities.

Before Congress enacted the Resource Conservation and Recovery Act (RCRA) in 1976, relatively few States had regulatory programs dealing with hazardous waste. Experience with conventional forms of industrial and municipal solid waste had given the States little preparation for dealing with hazardous waste, many of which are chemically stable and thus extremely persistent under most conditions.

Studies across the Nation revealed that the disposal of hazardous waste decades earlier had left undetermined, but possibly very large, amounts of dangerous substances in and on the land. Moreover, wastes were leaking from many hazardous waste sites, some of which were closed. RCRA did not effectively deal with these old, often abandoned, sites because it was primarily concerned with proper management and permitting of present and future hazardous waste. In order to deal with the many substantiated and potential hazards posed by uncontrolled hazardous waste sites, Congress passed the Comprehensive Environmental, Response, Compensation, and Liability Act of 1980 (CERCLA), better known as Superfund.

Adverse health effects attributable to hazardous waste remain inadequately documented. However, a 1980 survey by the Environmental Protection Agency (EPA)[1] of 350 uncontrolled hazardous waste sites indicated substantial threats to the public. At the time, these were essentially all the sites for which there was detailed information. There are currently more than 15,000 uncontrolled sites in EPA's Emergency and Remedial Response Information System. The survey found:

- contamination of ground waters and reservoirs, affecting water supplies of 168 communities;
- contamination of drinking water wells leading to closure of at least 468 individual wells; and
- a total of 108 other adverse incidents, including damage to human health, natural

---

*Leachate is liquid resulting from the interaction of water with waste. The source of the water may be rain, inflow of ground or surface waters, or other waste.

[1] "Damages and Threats Caused by Hazardous Waste Sites" (Washington, D.C.: Environmental Protection Agency, 1980).

habitats, fish and livestock, crops, sewer systems, and soils.

Furthermore, an unreleased EPA study, in progress for several years, indicates there are 80,263 sites in the Nation with contaminated surface impoundments (pits, ponds, and lagoons).[2] Ninety percent are believed to pose at least a potential threat of ground water contamination. Another unreleased EPA study reports that testing of underground drinking water supplies in 954 cities found contamination in 29 percent. All the affected areas had populations of more than 10,000.[3] Leaching of toxic substances from waste landfills is believed to be a contributory factor in these cases.

Long-term health effects from exposure to hazardous waste are uncertain, but they may be serious. For example, in one case of contaminated drinking water (associated with a hazardous waste dump in Hardeman County, Tenn.), the levels of carbon tetrachloride were so high that they exceeded proposed water quality criteria by a factor of 10,000.[4] EPA has said that of the 418 uncontrolled hazardous waste sites in the Nation that need priority attention, 347 pose direct threats to drinking water supplies and could cause birth defects, cancer, and other diseases.[5]

Although information is scanty on the amounts and types of releases, many hazardous wastes are persistent, mobile, and highly toxic. It is possible that large segments of the population are being exposed to releases of hazardous waste constituents. As much as 80 percent of federally regulated hazardous waste—at least 30 million tonnes per year—are being placed in or on the land. An even greater percentage of the 255 million to 275 million tonnes of hazardous waste under Federal and State regulation may be land disposed. Therefore, under current practice, 1 tonne of hazardous waste is added to the environment for every person in the Nation every year. The accumulation from past decades of industrial activity is equivalent to several tonnes of hazardous waste for every person in the Nation. Furthermore, waste management techniques other than land disposal, such as the burning of waste in boilers, cement kilns, and incinerators, may be releasing hazardous substances into the environment.

The Tradeoff Between Near- and Long-Term Costs

The economic costs of hazardous waste are substantial. Industry and governments are currently spending $4 billion to $5 billion annually to manage regulated hazardous waste. Assuming a continuation of present Federal RCRA and CERCLA programs and modest increases in hazardous waste generation, annual costs are estimated to rise to more than $12 billion (in 1981 dollars) in 1990. If more wastes are regulated, if more major cleanup actions are required, and if compensation is required for damages to health and environment, then future costs could be much greater. Government spending will increase substantially as RCRA and CERCLA implementation becomes more intensive.

The cost of cleaning up uncontrolled sites and compensating for damages to human health and the environment calls for consideration of the full "lifecycle" costs of managing hazardous waste. From an economic perspective, the overriding hazardous waste issue of today is: **Would it be more prudent and effective in the long term to increase the stringency of current land disposal regulations and encourage the use of alternatives to land disposal, even though near-term costs might be increased?** Attempting to minimize present costs will almost certainly lead to a transfer of greater costs to the future. Moreover, failure to improve waste management in the near term would surely lead to unacceptable health and environmental effects in the long term. It should be stressed that the language of RCRA precludes balancing costs and risks; rather, it places sole emphasis on the protection of public health and the environment.

---

[2] As reported in *The New York Times*, Dec. 30, 1982.

[3] As reported in *Engineering Times*, September 1982.

[4] Samuel S. Epstein, et al., *Hazardous Waste in America*, Sierra Club Books, 1982.

[5] As reported in *The Washington Post*, Dec. 21, 1982.

The cost to assess and clean up an uncontrolled site ranges from several hundred thousand dollars to tens of millions of dollars. For example, the cost to clean up one site in Seymour, Ind., has been estimated at $22.7 million. To clean up four sites in St. Louis, Mich., one company has agreed to spend $38.5 million. Hydrogeologic investigations to define the extent of ground-water contamination can cost from $25,000 to $250,000. The average cost for cleaning up and containing contaminated ground water ranges from $5 million to $10 million a site; the cost of totally restoring a badly contaminated aquifer to potable quality could be 10 times the average cost.

To clean up a substantial fraction of the more than 15,000 presently known uncontrolled hazardous waste sites is likely to cost, in public and private spending, a total of $10 billion to $40 billion. This should be compared with the estimated $1.6 billion to be collected under CERCLA by 1985. CERCLA funds are meant to be used for cleaning up uncontrolled sites where no responsible party can be identified, and for advancing funds for cleanup before recovery from responsible parties is made. The cost of cleaning up known sites is not likely to be the end of the expense. Still more uncontrolled sites are being discovered, and probably some are being created by current practices and exemptions.

It is generally acknowledged that, even with the new stricter RCRA regulations in place, eventual releases of hazardous constituents from land disposal facilities are highly probable. Greater use of waste treatment alternatives is, therefore, a major issue, although they too, if not regulated effectively, can release hazardous constituents to the environment. Yet greater use of alternatives to land disposal—treatment, recycling, and especially more investment in waste reduction—could increase industry's near-term costs significantly, perhaps by as much as 50 to 100 percent. But years or decades from now, cleaning up a site from which there are hazardous releases, and compensating victims, might cost **10 to 100 times** the additional costs incurred today to prevent releases of hazardous materials.

For example, in the case of Love Canal, it has been estimated that disposal of the waste dumped there decades ago—according to the standards and practices of today—would have cost $2 million (in 1979 dollars)* versus $36 million for remedial action already spent through 1980. Ultimate costs for remedial action are expected to exceed $100 million; in addition about $2 billion in lawsuits have been filed by persons claiming damages.

EPA estimates that the average cost of disposing of hazardous waste in compliance with the new RCRA regulations is about $90 per tonne. The EPA estimate of the cost of cleaning up improperly dumped waste is up to about $2,000 per tonne. In addition, much of the burden of future costs would likely fall on the general public. Costs incurred today by improved management of hazardous waste would be borne, more equitably, by waste generators and by consumers of "hazardous waste-intensive" products.

---

*This is not to suggest that the technical factors alone were responsible for the Love Canal problems.

SELECTED READINGS

CHANGING ROLE OF ECONOMICS

Environmental Quality 1981

12th Annual Report of the Council on Environmental Quality

1

The Environment and National Values

Perspective

From the earliest settlers to the millions of campers who now crowd the national parks, Americans have always sensed the importance of the nation's air, water, land, and other natural resources. Their development and use through the creative drive of the American spirit has led to the most prosperous nation in history. Yet national attitudes toward different, and sometimes competing, uses of these natural resources have varied over time, evolving as the nation's population multiplied, as its economic system grew, and as new technologies developed.

This evolution of environmental attitudes has not always been quiet. It is rooted in a long history of national debate over the appreciation, use, and management of the nation's environmental resources. Central to much of this debate have been two questions: First, what is the optimal mix of uses of the nation's water, land, and other natural resources? Second, how should private and public management of these resources be balanced?

With the creation of the United States, there emerged in this hemisphere a respect for the concept of a free market economy and the common law tradition of private property rights. Regarding the land, property rights were originally assigned by the British Crown and later by colonial governments. However, there were, and are, few precedents for assigning property rights to other natural resources such as air, water, or wildlife. Indeed, such resources rarely have been treated as property. At first, they were sufficiently plentiful that questions of scarcity and equitable distribution did not arise. Hence, at that time, there was little incentive to encourage their protection and little involvement of the government in their management.

That situation began to change in response to a number of social, economic and political factors. Throughout the nineteenth century the land was increasingly settled and political conflict began to develop among competing interest groups. Growing prosperity and more schools led to the emergence of an educated middle-class. With the scientific revolution came an increasingly popular notion that natural resources could be scientifically managed. These and other forces led to an expanded governmental role in dealing with environmental issues. Beginning especially with the Administration of President Theodore Roosevelt, an ever greater reliance has come to be placed upon the use of federal regulation to manage the nation's resources.

The Council feels that perhaps the pendulum has swung too far in the direction of reliance on governmental regulation to solve environmental problems. While it believes that a certain degree of regulation is required, it also feels that the nation has not sufficiently utilized free market principles as an effective ally of environmental protection.

The Council believes that responsible management of natural resources requires responsible choices among conflicting needs, not single-minded advocacy of special interests. It requires resource conservation in concert with economic development, not resource conservation versus economic development. While a strong and continuing role by the federal government is certainly necessary, many environmental issues are most amenable to state and local resolution, and to resolution within the private sector. It should be remembered that of the billions of dollars which have been expended on pollution control in the United States during the past two decades, the large majority of these funds has been private, not public, sector resources. Certainly, a large portion of pollution control expenditures by private industry has been in response to the imposition of government regulations. At the same time, a portion of expenditures in this area has been influenced by industries' increasing environmental conscienceness and a growing awarenness that the generation of industrial wastes, in fact, represents lost opportunities for profit.

The Council believes that the federal government should assist, not dominate, state and local governments and private parties as they all work together toward ensuring a "productive harmony between man and nature" as called for in the National Environmental Policy Act of 1969 (NEPA).

This, the Council's Twelfth Annual Report to the Congress, summarizes the current status of the environment and considers each major area of environmental quality in the context of its historical development as a national concern.

" . . . Where We've Been"

The First Hundred Years (1776-1871)

The basic questions regarding environmental management have not changed. Just as past generations have had to define the optimum value and use of environmental resources for themselves and their posterity, so do people today. Just as past generations have had to determine the different functions of the public sector and private enterprise in developing natural resources, so do people today. And, just as population levels, economic development, and technological capability have helped to shape the environmental attitudes of past generations, so too will these factors influence value judgements today.

For the early colonists, environmental values were dominated by the need for survival, both physical and economic. Because in those precarious times when human labor was more scarce than natural resources, it is understandable that they valued these resources less than we do today. The early colonists made little effort to ensure continued yields from virgin forests or to protect wildlife. Nor did they practice methods of farming which preserved or replenished surface soils. Instead, they responded in a resourceful way to both the problems and possibilities posed by a seemingly limitless wilderness.

During the century after 1776 the federal government bought, or was ceded, vast areas of land which were added to the territory of the United States. The midwestern land claims of the original states expanded the new nation's boundaries, and successive events—the Louisiana Purchase (1803), the Oregon Compromise (1846), the Treaty of Guadalupe Hidalgo (1848), the Gadsden Purchase (1853), and the Alaska Purchase (1867)—added 1.8 billion acres to this young country. The federal government continued the common colonial practice of assigning property rights to new lands by distributing rights through sales, homesteading, and land grants to military veterans, states, local governments, and railroads.

The abundance of land contributed to the uniqueness of America. Instead of the republic of classical antiquity—territorially small, ethnically homogenous, socially conservative, and economically stable—the American republic became big, diverse, exuberant, innovative, and expansive. Slow, planned growth favored by many eastern politicians was replaced by the sprawling, brawling, impatient expansion that characterized the American frontier. America became a republic of hope, opportunity, experimentation, mobility, and personal independence.

The first land laws established a policy of orderly land surveys marching westward across the country in a regular pattern with the eastern-most tracts of land being offered for sale first at a price high enough to provide substantial revenue to the U.S. Government. But the settlers did not hold to this theory. Settlement largely preceded survey and Congress, with reluctance at first, but soon with more enthusiasm, revised the land laws in an attempt to meet reality. The minimum price and the minimum acreage requirement were reduced. An experiment in offering land on credit was tried and abandoned. Provision was made for squatters to purchase the land they occupied at the minimum price once the survey caught up with them. Land was given to the states for public purposes. Finally, during the Lincoln Administration, land was given outright to legitimate settlers, to transcontinental railroads, and to states to promote higher education.

The easing of the terms of sale by the government is only part of the history of the public land. The settlers found even these liberal land policies to be too confining and they developed techniques to thwart the intent of the law. Settlers created claim clubs which acted to prohibit competitive bids on member's land claims, to force sales at minimum prices, and to defend the accuracy of fraudulent claims. Speculators and settlers alike found ways to patent tracts of land larger than permitted by law. Ranchers, lumbermen, and miners used the federal estate as if it was their own private domain. The growth of America through this period was an exciting, heady, unplanned, successful adventure where the risks were great but also where fortunes could be made.

This expansionary time, often referred to as the period of "manifest destiny," saw settlers move as far as the Pacific coast and Texas to tap the abundant resources for their individual benefit. Though certain excesses may affront our modern sensibilities, the settlement of the land and the development of the resources created the wealth necessary to settle the continent, fight a great civil war, secure the Union and end slavery, provide a new home for millions of immigrants, and establish the first middle-class society known to history. At the same time, while the push westward was taking place, a few people began to speak out about what was perceived as shortsightedness in such rampant expansion. They sought to promote the idea of resource conservation.

The Awakening of Conservationism (1872-1910)

By the last quarter of the 19th century, with the completion of the coast-to-coast railroad and the closing of the frontier, land-use reformers drew public attention to the adverse results of unplanned and unregulated exploitation of the nation's natural resources. For example, in 1871 a forest fire destroyed Peshtigo, Wisconsin, killing 1,500 people. The fire was blamed on the cutting methods and waste associated with unregulated timber companies. In the East the Erie Canal was believed to be drying up because of logging in the Adirondacks. The closing of the frontier, together with a growing belief by many that the nation's resources were being exhausted at an alarming rate, led to a clamor for government intervention.

By 1867, all the land area that was to become the continental United States had been acquired by the U.S. Government. However, in 1871 the federal government withdrew 2 million acres from the public domain in order to create Yellowstone, the first national park. This action marked the beginning of a new course in national lands policy.

Active federal management of natural resources began in earnest in the 1890s, and the political forces which led to this increase in government involvement came to be known as the progressive conservation movement. One aspect of this movement was based on the belief that an enlightened technocracy, supported by the political power of the federal government, was the best means for ensuring that the nation's natural resources would be developed for the maximum economic advantage of both present and future generations.

The ideals of progressive conservation manifested themselves again and again in federal law and administration. In 1891, the Forest Reserve Acts authorized the President to establish national forest reserves. By 1899, 33 million acres had been set aside; by 1908, 132 million more acres had been added. In 1902, the Reclamation Acts were passed, authorizing the proceeds from western land sales to finance the construction of dams and reservoirs to irrigate arid western lands.

The progressive conservation movement peaked in 1908, with President Theodore Roosevelt's White House conference on conservation. On that occasion, President Roosevelt expressed his belief in the importance of national action to preserve natural resources:

> ''*The wise use of all of our natural resources, which are our national resources as well, is the great material question of today. I have asked you to come together now because of the enormous consumption of these resources, and the threat of imminent exhaustion of some of them, due to reckless and wasteful use, . . .*''

5

Even though the perceived threat of resource exhaustion never materialized, Theodore Roosevelt's Administration was the first to weave federal ownership and management of resources into the fabric of national policy.

Conservation vs Preservation (1911-1932)

The primary principle of progressive conservationists—"the greatest good for the greatest number for the longest time"—was much applauded at the turn of the century. Yet disagreements over the definition of "the greatest good" led to public disputes between the progressive conservationists and the preservationists, a group that on the surface at least seemed to be a natural ally.

The preservationists were led by John Muir, founder of the Sierra Club. They believed in the value of wilderness as wilderness. Whereas the progressive conservationists valued natural resources for their economic utility, the preservationists believed that "the greatest good" from natural resources included the beauty, health, and spiritual nourishment derived from untouched nature.

Both groups agreed that government involvement was needed to counteract the alleged waste of resources associated with private development. The different values they applied to different natural resource uses led to public disagreements over specific development projects. One famous controversy involved a proposal to dam the Hetch-Hetchy Valley in Yosemite National Park as a publicly-owned water reservoir for the city of San Francisco. For almost a decade the progressive conservationists argued that the water reservoir was more valuable to society than the picturesque valley; the preservationists countered that the valley was worth far more in its primitive state, especially because water was available from a number of other sources. In 1914, the progressive conservationists prevailed and Congress authorized funding for the reservoir.

These two conflicting value systems sometimes were reflected within the federal government itself. For example, the Forest Service, which had evolved within the Department of Agriculture, had been given responsibility for managing more than 150 million acres of federal forest preserves. In 1905 these preserves were made national forests. The Forest Service cut roads, harvested timber, and worked to prevent and control fires in the development-oriented tradition of the progressive conservationists. On the other hand, the National Park Service, established within the Department of the Interior in 1916, was responsible for the protection of undeveloped wilderness areas, a role supported enthusiastically by preservationist groups.

The use of the nation's waterways also was a public issue during this period. For nearly two decades Congress debated whether inland waterways were to be used primarily for navigation, or for a broader range of purposes such as water reservoirs and electricity production. Once again individuals and organizations in the private sector strongly supported their own interests, while government agencies argued various positions. The U.S. Army Corps of Engineers believed that navigation and commerical transportation were the most efficient uses of inland waterways, and that levees would best control floods; the Forest Service and the Department of the Interior argued for multi-purpose development. With the passage of the Water Power Act in 1920, which provided for public control of hydroelectric development, navigation was retained as a higher national priority than multiple uses.

Although succeeding administrations acquiesced in and reaffirmed the commitment to continued federal ownership and management of natural resources, they also responded to a public reaction against the growing regulatory presence of the federal government. After World War I there was broad popular sentiment to reduce the role of the federal government. During the 1920s, three presidents were elected with a mandate to restore individual freedoms in the marketplace and to enhance state and local government roles in the public sector.

To some, the 1920s seemed to be a decade of substantial improvement in the effectiveness and responsiveness of government management of the environment. Under Presidents Calvin Coolidge and Herbert Hoover, the federal conservation agencies consolidated and strengthened their missions. New laws created federal-state cooperative programs in such areas as fire protection and reforestation, as well as research programs in forestry, water resources, and soil conservation. Sustained yield management was developed and applied, and forestry and wildlife management were developed and adapted. The giant Hoover Dam project was begun.

Despite the progress, disputes continued: Should the states or the federal government control water in the West? Who should hold grazing rights to public lands? Should the public or private sector control mining on public lands? These questions persisted until political and economic circumstances changed dramatically with the Depression.

Expansion of the Federal Role (1933-1969)

The nation's evaluation of public resources continued to evolve between the First and Second World Wars, and was reflected in the policies of government agencies. For example, reservoirs constructed with government funds to irrigate arid lands came to be used increasingly for fishing and boating. Also the Forest Service began to develop recreational uses of the National Forests, and parts of them were precluded from commercial timber harvesting. Yet the most profound change in policy during this period was the emergence of the federal government as a dominating factor in managing public resources. This expanded role paralleled similar increased authority in almost every sector of the U.S. economy.

Among the array of federal actions which President Franklin D. Roosevelt initiated during his first months in offfice were two which affected U.S. resource conservation: the establishment of the Civilian Conservation Corps (CCC) and the Tennessee Valley Authority (TVA). The CCC hired 2 million people to work in several thousand camps on such diverse conservation projects as massive tree plantings, park development, waterways improvement, flood control, rangeland development, reclamation, and wildlife protection. The efforts of the CCC to control soil erosion led to the creation of the Soil Conservation Service in 1935, and federal activities in that area continued to expand.

Besides using federal law and funding to develop natural resources and jobs, the founders of the TVA believed that only a new form of regional government responding to both economic and natural resource issues—jobs, hydroelectrical power production, erosion control, reforestation, navigation, and flood control—could solve the interrelated problems of the Depression.

The federal impact on resource conservation manifested itself in a number of other areas. In 1934, the Taylor Grazing Act established the general rangeland management authority of the federal government. The Act effectively ended homesteading in the contiguous United States and established in the Department of Interior a Division of Grazing, which was to become the Bureau of Land Management. This new federal office was responsible for allocating grazing rights on federal land, collecting grazing fees, and establishing restrictions and controls on the use of range resources.

Conflicts between competing uses of publicly owned resources led to passage of the Multiple Use-Sustained Yield Act of 1960. This legislation required the Forest Service and Bureau of Land Management to attempt to balance outdoor recreation, rangeland, timber, watershed, fish and wildlife habitats, mineral extraction, and other uses in an effort to provide the optimal value to the nation as a whole. The notion of multiple use echoed the earlier conflicts between the developmental sentiments of progressive conservationists and preservationist concerns for the maintenance of wilderness areas for aesthetic and recreational purposes. Yet multiple use legislation remained inadequate for resolving conflicts between competing, mutually exclusive uses.

The Environmental Decade (1970-1980)

A federal water pollution control law was passed in 1948, and in 1955 federal funds were appropriated to begin studying air quality problems. In addition, during the 1950s and 1960s, U.S. industry began to spend substantial sums on pollution control. However, for many, the 1970s have come to be known as the environmental decade. Until the 1970s the federal role in environmental regulation was generally limited to the management of publicly owned land, timber, minerals, and waterways. This situation began to change dramatically when the National Environmental Policy Act (NEPA) was signed into law on January 1, 1970, by President Richard Nixon.

By the 1970s throughout the nation, in industry, government and among the people at large, there was a heightened consciousness of human and ecological interdependence. This was the result of various factors including the growth of the population, the continuing trend toward urbanization and industrialization, and the post-war development of new products for a host of different purposes, combined with new scientific understanding of pollution effects and available national wealth necessary to pay for environmental improvement. There was a growing recognition that human activities at one place affected other people, at greater distances, over longer time spans, and in ways significantly different and not clearly recognized or understood from past experiences.

During the decade of the 1970s, two dozen separate pieces of legislation either expanded federal intervention in traditional resource areas or introduced the federal government into wholly new areas. By 1979, the federal government was writing and enforcing regulations affecting occupational safety and health, resource recovery, noise, water quality, air quality, pesticides, endangered species, drinking water, toxic substances, hazardous wastes, mine safety, coastal zones, ocean pollution, the outer continental shelf, and the upper atmosphere.

"... Where We Are ..."

The Accomplishments

Throughout the nation's history, the definition and redefinition of environmental values have been reflected with remarkable fluidity by federal government policy. Whereas at the turn of the century popular environmental concern was focused almost exclusively on the quantitative use of public resources such as land, timber, and surface water, it now encompasses a wide range of environmental quality issues reflecting a growing consciousness of the interdependency of the physical universe and of its combined effect on people's health and welfare. The ongoing public debate and the resulting level of public consciousness must be considered a major accomplishment in itself.

Growing prosperity and a demand for amenity values have produced a growing interest on the part of individuals, industry and government to improve the quality of the environment. During the past decade, this interest has resulted in a formidable array of federal legislation aimed at controlling adverse effects in almost every segment of the environment. The Council clearly recognizes that, whatever might be their shortcomings in terms of either costs or effectiveness, the host of laws now on the books is a public policy manifestation of the nation's wish to protect the quality of the environment.

The Council further believes that the nation's environmental and natural resource accomplishments are by no means limited to symbolic expressions of national values. In many cases legislation passed during the last century has led to tangible benefits for generations of citizens. For example, millions of acres of western arid lands have been irrigated for food production. The desert southwest, which early explorers thought unfit for human habitation, is now a major population center. The Bureau of Land Management and the Forest Service manage more than 600 million acres for legislatively mandated multiple purposes. The Fish and Wildlife Service and the National Park Service manage more than 50 million acres for the protection of wildlife and wilderness areas. Although a number of species of plants and animals still are threatened or endangered, other previously endangered species now are surviving in protected habitats managed by both public and private interests.

Furthermore, recent environmental legislation together with significant technological achievements by American industry have resulted in substantial improvements in environmental quality. Air quality in the United States, especially in urban areas, has improved measurably during the past decade. Cities such as Pittsburgh and Los Angeles, which had suffered from long-term air quality problems, have experienced sharply lower numbers of air quality alerts during the past several years. Automobiles produced in 1980 emitted 90 percent less hydrocarbon and carbon monoxide and 75 percent less nitrogen oxide than models produced in the 1960s. The legislation which fostered these improvements may not be faultless, but the air quality achievements cannot be denied.

Examples of improved water quality are evident across the United States. The Willamette River in Oregon, the Penobscot and Winooski Rivers in the northeast, the Cuyahoga River in Ohio, the Great Lakes in general, the lower Savannah and Chattahoochee Rivers in the southeast, and the Potomac River south of the nation's capital—all have shown substantial improvement over the quality of 10 or 20 years ago.

The people of the United States have come to realize that the proper management of natural resources, such as air, water, timber, and minerals, can enhance the quality of life for people living in other communities, states, and countries. From the long-term perspective of geopolitical stability, the realization that this nation's environment-related activities affected every other nation is itself an important accomplishment.

The Costs

Time after time in this nation's history, various groups have argued for different uses of publicly owned resources. And time after time the political process—lobbying, legislation, regulation—has registered the nation's commitment to environmental protection. Yet often, when one action has been undertaken, the full social costs of precluding other actions have not always been adequately considered. Often legislation passed to appease one segment of the public interest has been judged to run counter to the interests of another segment or later found to be counter to the general public good.

There also has been a high cost in capital and lost opportunities for other uses of that capital. That cost sometimes has been explicit, e.g., when the federal government pays percentages of the cost of a publicly owned wastewater treatment plant with budgeted tax money. It has been less explicit when the government imposes a cost on another party, e.g., when the government regulates air emissions from utility smokestacks. These capital costs can be made especially severe if there is inadequate analysis or incomplete understanding of secondary consequences. All too often legislation to enhance environmental quality has placed restrictions on the methods of achieving that quality, thus impeding economic forces from working to minimize compliance costs.

Some cost also has been exacted on the good will and cooperative spirit of citizens throughout the country. In some cases environmental legislation established unrealistic schedules for meeting environmental goals. Although it is often useful to set a high target in order to hit a high mark, the loss of public interest and support when unattainable goals are not reached should not be discounted.

Another cost associated with the enviromental accomplishments of the past century has been an inappropriate involvement of the federal government. While federal action is necessary to rectify some environmental abuses and to establish equity among the states, the rising flood of environmental legislation, especially during the past decade, has created the impression that the only recourse for attaining a cleaner environment is more federal action.

The full costs in capital and in lost resource use associated with current environmental legislation are now beginning to be recognized. Many of the laws passed during the 1970s introduced the federal government into new areas of natural resource management; it is not surprising, therefore, that several years' experience with that legislation has shown that it imposed unforeseen costs or that it failed to address unforeseen problems. The rigidity and complexity of recent environmental regulations have hindered the nation's traditional ability to respond flexibly to an evolving value system with evolving institutions.

The Lessons

The most striking lesson to be learned from a review of the nation's environmental history is that resources held in common, that is, resources which have not been assigned as a property right, have almost inevitably deteriorated. The western rangelands, which the federal government reserved as public property and intially opened up to all who chose to graze them, were soon denuded of vegetation and then eroded. Consequently, the government began to regulate, with a mixed record of success, the amount of allowable grazing in order to preserve the quality of publicly owned rangeland. For the same reason, in most cases, the rights to western surface water were assigned to individual, state, and federal users as soon as it became clear that unregulated water withdrawals would dry up surface water supplies.

A similar situation exists today in relation to the nation's air quality and ground water supplies. Until recently, the air has been considered a common and infinite resource. Anyone could discharge any amount of pollutants into the air as often as needed, because the air belonged to everyone and no one. Only when it was recognized that air pollutant emissions adversely affect other air users and that air quality is subject to the same deterioration as overgrazed rangeland have people begun to think of clean air as property. As with other property, access to it must be assigned or regulated in order to preserve its quality both in the short and long term.

Several different parts of the country are beginning to suffer from declining ground water quantity and quality. Again, the problem is often a direct outcome of the fact that in many places ground water is considered common property, and anyone can drill and extract as much water as desired. For example, the extensive Ogalalla Aquifer in the midwestern United States is being depleted rapidly by thousands of different wells. In the East, some problems regarding the quality of ground water sources used for public drinking water supplies are emerging because of contamination caused by improper disposal of toxic chemicals.

The government has a century-old tradition of directly assigning rights to publicly owned property. The government assigns rights when it licenses private logging companies to cut timber on federal property; it assigns rights when it rents spaces in public campgrounds. As the example of western rangelands demonstrates, the government usually is forced to assign these rights when it becomes apparent that the resource in question will be useful to no one if everyone has equal and unlimited access to it.

In assigning such rights the government, in effect, establishes a value for that right through the levels of user fees, license fees and the like which it charges for a particluar activity. As the history of public lands in the West demonstrates, the government tends to undervalue public resources largely because of the pressures imposed by self-interested users. This failure to set optimal user fees has contributed to the deterioration of public resources in the long term. Further, the inefficiencies that inevitably arise when the central government makes market judgements are compounded by the fact that the government's evaluation, even when based more or less accurately on the market forces at the time, tends to become institutionalized and therefore more difficult to change as national values change. Too often, federal action predicated on the present value of public resources precludes possible and perhaps more efficient future uses.

Likewise, federal government actions to solve environmental problems, while theoretically in the best interests of the country as a whole, often are impractical when applied at the local level. For example, in response to growing water quality problems related to sewage disposal, the federal government has funded a large-scale construction grants program for municipal sewage treatment facilities. Unfortunately, the type of facility generally funded under the program, while appropriate for high-density urban areas, may not suit the needs of sparsely populated rural areas. In fact, the existence of such a large-scale federal program may inhibit consideration of alternative sewage disposal systems more appropriate to local circumstances.

Finally, the history of national concern over the quality and quantity of natural resources demonstrates that the nation's understanding of environmental problems will evolve over time, as will its response to those problems. Just as the industry of one generation has caused unforeseen problems for the next, so have the environmental problems of one generation been confronted, and sometimes resolved, by the next. But if the nation is to continue to respond effectively to changing environmental circumstances, the laws of one generation cannot prescribe environmental legislation and regulations in such detail as to impede future, perhaps more informed efforts to protect environmental quality.

"Where We're Going . . ."

The environmental activity during the 1970s climaxed a century of gradually increasing public and private consciousness of environmental quality. By the 1970s, it seemed that because publicly owned natural resources had been undervalued by all parties using them, they rapidly were losing their value to both present and future generations. Far more environmental legislation was passed in that decade than in any similar period, as the nation faced the short-term and long-term economic and social implications of environmental deterioration.

If only because the nation enacted such a wide range of legislation in the 1970s, the 1980s undoubtedly will be a period of reevaluation, both of perceived environmental problems and the effectiveness of proposed solutions. For example, because the effects of ambient air quality on human health were of primary concern at the beginning of the 1970s, the Clean Air Act required the setting of ambient air quality standards for major air pollutants. In order to protect the health of people living close to sources of air pollution, some owners of emission sources constructed tall stacks to disperse air pollutants over much wider areas, thus ensuring that air quality standards close to the source were not violated. This method of diluting and dispersing pollutants, although responsive to the concerns of the Clean Air Act, may have contributed inadvertently to another environmental phenomenon given little attention in the early 1970s—acid precipitation. Because the response to one environmental problem may have contributed to another, the national response to both should be reevaluated.

Prior value judgments on the optimal use of public lands in the West were made when this country enjoyed ample supplies of inexpensive liquid fuels produced both domestically and in foreign countries. That situation has changed dramatically during the past decade. Because international political instability poses a threat to the U.S. economic and social system, the value of domestically owned energy resources has increased sharply. Today, the federal government owns a large part of these domestic energy resources, which include oil, natural gas, coal, oil shale, and tar sands. During the coming decade the nation will be reevaluating its prescribed uses for public resources in the context of a radically altered energy situation. The relative value of clean air, scenic vistas, agricultural water use, and pristine wilderness areas will be weighed against the economic and national security value of domestic mineral and energy supplies. As in the past, conflicts between competing uses will be decided in the political arena, as the issues are debated by the Congress, within the Administration, by interest groups, and private citizens.

This kind of thinking should extend to environmental standards, control technologies, natural resource user fees, compliance alternatives, and the definition of environmental problems themselves. The air quality standard for particulates should be reassessed in light of the widely varied effects of different sizes of airborne particles. Alternative methods of human waste disposal, especially those that use substantially less potable water, should be considered. The benefits of controlling "non-point" sources of water pollution (such as runoff from farms and cities) should be balanced against the benefits accrued from continuing to tighten controls on "point" sources (such as waste treatment plant discharges) which have been the prior focus of water quality regulations. All the various users of public lands, whether logging or energy companies, recreationists, campers, or ranchers, should pay user fees commensurate with the value received. This reevaluation of the nation's environmental problems and the public's responses should, as appropriate, lead to changes in current standards and regulations. More important, it should lead to a more efficient and equitable use of the nation's natural resources.

During the coming years the federal response to this reevaluation of environmental programs will be shaped by several principles to which the current Administration is committed. Important among them will be:

- Balancing costs and benefits,
- Allowing the marketplace to work,
- Decentralizing government responsibilities, and
- Continuing global cooperation.

Balancing Costs and Benefits

The environmental fervor of the 1970s arose in part from the perception that commonly enjoyed property such as air and water were needed to do business, but businesses were not paying for their use. The emission of air pollutants was one of the costs of producing goods or energy. The effect of pesticide and fertilizer runoff into streams was one of the costs of producing food. Despoiling scenic vistas was one of the costs of logging and energy development on public lands. Yet these costs were not being internalized; that is, private businesses through their customers were not paying the full costs of using common pool or publicly owned resources. In fact, these costs were being imposed on the public at large.

Legislation in the 1970s began to force private parties to recognize environmental costs explicitly. The Clean Air Act, the Clean Water Act, and the Surface Mining Act, among others, enforced pollution standards that required potential emitters either to limit discharges of pollutants into the commons or to restore the commons after disruption. The costs of avoiding or ameliorating environmental damage thus were forcibly internalized by the private sector.

During the 1970s, the federal government also was required to recognize explicitly the environmental costs of federal activities. The environmental impact statement process mandated by the National Environmental Policy Act (NEPA) required the federal government to study environmental effects, costs, mitigating measures, and alternatives to major federal actions. Although not usually described as a statement of national economic philosophy, NEPA nevertheless includes the analysis of environmental costs in the public decisionmaking process of the federal government.

Despite the best of intentions, past experience with the environmental legislation of the 1970s has demonstrated that an overly rigid attempt to internalize environmental costs may impose other costs that are out of proportion to the benefits accruing to society. Incremental increases in the costs of controlling automobile emissions may be difficult to justify in terms of health benefits. Restrictions on the development of privately owned land adjacent to national parks may be difficult to justify in terms of the aesthetic benefits of integrated vistas. The environmental impact statement process imposed unforeseen costs related to program administration, impact statement preparation, and project delay. Because private capital and the federal budget are limited, these costs must be considered in evaluating different approaches to environmental protection. Complicating this issue further is the fact that costs and benefits on matters of environmental protection are difficult to measure, because environmental values are often highly subjective.

In the 1980s the costs involved in using public resources in the course of private business or individual consumption should be made explicit. For example, the cost of disposing of hazardous wastes should be paid through increased user rates by the customers of the industries that create those wastes. Only if the costs of public resource use are internalized explicitly will those resources be used most efficiently. Environmental standards should be set based upon the environment's natural assimilative capacity, scientifically verified health needs, and the economic well-being of the nation as a whole. The private sector should then be encouraged to attain such environmental standards in the most cost-effective manner. An economic system which recognizes the costs of using natural resources and the costs of controlling adverse environmental effects, and which attempts to balance these costs with the benefits of enhanced human health and efficient economic development will be a strong ally in both the short and long term conservation of natural resources.

Allowing the Marketplace to Work

Whenever possible, the achievement of environmental goals and the protection of environmental standards should be left to free market mechanisms. If all the social and economic costs attendant upon evironmental protection are taken into account, the marketplace should accurately define the most efficient method of protecting environmental quality while making sure that the public interest is served most efficiently.

In the past, marketplace forces have not been sufficiently applied to determine either the use of publicly owned natural resources or to control the degradation of the environmental commons. In fact, since the Administration of President Franklin D. Roosevelt, such thinking has all but fallen out of fashion. Instead, the federal government has tended to make large-scale economic value judgments, in favor of river basin development, for example, which often have contributed inadvertently to the deterioration of the environment.

The federal government has provided some private interests with various kinds of federal subsidies intended to encourage economic activity or to provide relief from economic disaster. For example, the federal government has subsidized the development of the East Coast and Gulf Coast barrier islands through a federally funded flood insurance program, a program which exists because private companies have refused to insure prospective developers of the ecologically sensitive and flood-prone islands. In reality, the federal insurance program has paid out millions of dollars of public funds to subsidize the inefficient development of an environmental resource. In recognition of this waste, the Omnibus Budget Reconciliation Act of 1981 provides that no new federal flood insurance coverage shall be provided after October 1, 1983, for new construction or substantial improvements located on undeveloped coastal barriers.

During the coming decade, government subsidies of various kinds will be reviewed in order to assess their value to the economy as a whole. This review should also include consideration of any potential environmental costs of such subsidies. The Council feels that, if the marketplace is to operate effectively in defense of the environment, the majority of such subsidies probably should be eliminated.

Market forces should also be used to achieve environmental standards in the most cost-effective way. For example, in order to control air pollutants efficiently, those major emission sources which cause the greatest harm should be controlled first. The sources that require the highest control cost relative to the benefits derived should be controlled last. The establishment of an emissions market would allow the trading of air emissions rights, thus encouraging the optimal control of air pollutants for any given level of capital investment. This kind of market approach holds the promise of protecting the common property of all citizens at the least cost to society.

Decentralizing Government Responsibilities

As has been pointed out, increasing numbers of natural resource and environmental problems have been passed on to the federal governmental for solution. However, centralization of responsibility at the federal level has brought its own problems. In many cases this is because a centralized authority tends to impose uniform solutions to problems across the country which may, in fact, vary considerably in character. For example, options for the ecologically sound disposal of human wastes differ widely, depending on population density and soil conditions, yet the federal government has, to a great extent, subsidized a uniform control technology.

Clearly, the federal government must continue to play an importat role in environmental protection and resource management. However, the federal government must recognize clearly that it is not the sole arbiter of natural resource values in this nation. The federal role should be one of supportive partnership with state and local governments and private individuals. The states should be given more authority and responsibility to determine the optimal use of natural resources within their borders.

The federal role should include setting national environmental standards to protect the health and welfare of the nation as a whole. While the federal government must maintain an oversight role in the enforcement of such standards to assure compliance, where feasible such enforcement should be delegated to the states. The federal government also should provide research, technical assistance and administrative oversight for addressing interregional problems such as the long-range transport of air pollutants. The federal government should continue to carry out the exchange of environmental ideas and information with other nations on particular environmental concerns, such as those with Canada regarding acid precipitation.

Continuing Global Cooperation

The globe is a shared resource, and the governments thereof share the responsibility to develop and use it wisely for both present and future generations. The United States has established a record of leadership in the protection of the environment and should continue to exert this leadership. This government should endeavor to work cooperatively with all nations, developed and developing, and with all responsible and relevant elements of the societies involved to attain this end. Just as in our domestic efforts, the U.S. Government should direct its primary attention towards the improvement of the scientific base for environmental actions, particularly in the more controversial and complex areas, e.g., ozone protection, acid precipitation, ocean pollution, and climate. In this regard, close liaison and exchange of information among national and international scientists and scientific research and development institutions, public and private, should continue to be encouraged, both in order to shed maximum light on the most significant global problems and to focus this light on the most cost-effective solutions.

The United States should continue to encourage responsible development and environmental protection by other countries with due respect for their own individual values and priorities.

NSF/PRA 83023

Workshop on

EFFECTS OF ENVIRONMENTAL REGULATION ON INDUSTRIAL COMPLIANCE COSTS AND TECHNOLOGICAL INNOVATION

Summary and Papers

NATIONAL SCIENCE FOUNDATION
Directorate for Scientific, Technological, and International Affairs
Division of Policy Research and Analysis

PRA Report 83-10
April 1983

Workshop on

Effects of Environmental Regulation on Industrial Compliance Costs and Technological Innovation

(Summary and Papers)

Washington, D.C.
September 10-11, 1981

National Science Foundation
Division of Policy Research and Analysis
Advanced Technologies and Resources Policy Group

FOREWORD

Major attention has been focused on pressures for and various initiatives advanced for regulatory reform in the United States. The case for regulatory reform rests on the perception held by many that economic performance, technological innovation, market structure, international competitiveness, and other economic and social factors are being negatively influenced by excessive or misdirected governmental regulatory activities.

The Reagan Administration has proposed a vigorous program of regulatory relief, overseen by a Presidential Task Force headed by Vice President Bush. Parts of the program are being implemented by the Office of Management and Budget (OMB) pursuant to Executive Order 12291 ("Federal Regulation") of February 17, 1981 and other directives such as the Paperwork Reduction Act.

Executive Order 12291 calls upon Executive Branch agencies to prepare regulatory impact analyses of proposed federal regulations as well as of existing regulations to assure that cost-effective approaches are utilized in attaining regulatory objectives. At OMB's request, the Advanced Technologies and Resources Policy Group* of the National Science Foundation has undertaken a program of studies on Environmental Regulation under my direction.

The first major component of this NSF program was a workshop, which was held September 10-11, 1981 in Washington, D.C. Participants included government officials, researchers, and representatives of industry and environmental organizations. Five research papers were originally commissioned, prepared, formally reviewed, revised, and then presented and discussed at the workshop. This volume contains three of the workshop papers, a summary of the workshop by its moderator, selected quotations from the edited proceedings of the workshop, and a list of participants. A companion volume (PRA Report 83-9) contains the edited verbatim proceedings of the workshop.

Richard E. Morrison
Senior Policy Analyst
Advanced Technologies and
Resources Policy Group

---

* At the time of the request the name of the Group was the Environment, Energy, and Resources Group, and all textual references to the Group are to its original name. The Group was renamed the Advanced Technologies and Resources Policy Group effective January 10, 1983.

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

PREFACE

The Advanced Technologies and Resources Policy Group of the National Science Foundation's Division of Policy Research and Analysis has conducted a series of workshops in response to interest expressed by the Executive Office of the President. These workshops have assessed Federal policy options relating to selected environment, energy, natural resource, and information technology issues.

Each workshop was structured to allow intensive discussion of an identified set of issues that impact Federal policies and programs. Initially, three to five papers were commissioned for each workshop from experts with a variety of backgrounds, experience, and constituencies. First draft papers were revised in light of reviews by other experts and interested parties from government, private industry, environmental, labor, and consumer organizations, research groups, and the academic community. The revised papers and reviewers' comments were then aired at a workshop attended by the authors, reviewers, and a variety of Federal policymakers. Areas of agreement and disagreement were illuminated and sharpened by the discussants. Finally, the papers were further revised for publication based on workshop discussions.

This document, prepared by National Science Foundation staff, contains three of the papers and a summary of a workshop on Effects of Environmental Regulation on Industrial Compliance Costs and Technological Innovation.

Frank L Huband

Frank L. Huband
Group Leader
Advanced Technologies and
Resources Policy Group

I. SUMMARY

Richard N.L. Andrews*

Purpose of the Workshop

The purpose of the workshop was to consider the effects of environmental regulation on industrial compliance costs, and on technological innovation.

The U.S. Office of Management and Budget (OMB) has authority to oversee all major regulatory activity of the Federal Government under Executive Order 12291 ("Federal Regulation"), issued February 17, 1981. This Executive Order calls on Executive Branch agencies to prepare regulatory impact analyses of proposed Federal regulations as well as of existing regulations, to assure that cost-effective approaches are used. It also authorizes OMB to set up a control system. This workshop aimed to help OMB and the agencies with these tasks, by bringing together and evaluating the existing methods of estimating costs, identifying what needs to be known, and exploring related issues that must be addressed in designing such a central control system.

The case for regulatory reform is based on the view held by many that some Federal Government regulations impose unnecessary or undesirable costs on the American economy, and that they reduce efficiency and equity. Many also believe that economic performance, technological innovation, market structure, international competitiveness, and other economic and social factors are negatively influenced by excessive, misdirected, or inconsistent governmental regulations.

The Administration is pursuing a program of regulatory relief, overseen by a Presidential Task Force headed by Vice President Bush, and implemented by OMB under Executive Order 12291 and other directives, such as the Paperwork Reduction Act.

Although there is a pressing demand to measure the costs and benefits of regulation, there is an equally pressing need to address the many uncertainties and problems involved in the development and implementation of regulations.

---

*Professor of Environmental Sciences and Engineering, and Director, Institute for Environmental Studies, University of North Carolina.

The Bottom Line: More Questions Than Answers

The workshop papers and discussion described and evaluated available techniques for measuring the cost of environmental regulation, and considered whether they overestimate or underestimate costs. However, the upshot of the workshop was that many questions remain unanswered, and many key decisions need to be made.

Workshop participants agreed that there are gaps in data and a lack of acceptable methodology to provide valid cost estimates for individual regulations, industrial sectors, or the economy as a whole. They concluded that estimation of the cost of environmental regulation is still in the experimental stage, as is the estimation of benefits.

The workshop discussions spanned a wide range of issues, including not only the specific question of how to measure costs of regulation, but also an explanation of the assumptions and larger questions that OMB needs to address before the estimators can do their work.

This summary reports on assumptions and decisions that need to be clarified in order for OMB to focus the cost estimation task more clearly. It then covers four areas that were central to the workshop discussions:

1. Can existing methods provide reliable estimates of the costs of particular regulations?
2. Do these methods tend to overestimate or underestimate regulatory costs?
3. Can the aggregate costs of Government regulation be managed?
4. What are the implications for those charged with implementing a central regulatory control system?

Need to Focus the Task More Clearly

Several decisions should be made in order to design a cost estimation system. Technical experts need more information about these three questions in order to proceed with methods for cost estimation.

Which Kinds of Regulations Should Be Considered? Environmental regulations differ in approach and in the object of the control, and they impose different kinds of costs. For example, a procedural regulation imposes primarily administrative overhead costs; a treatment technology requirement imposes primarily capital and operating costs; and an effluent quality standard or factor price surcharge simply imposes a new constraint on process engineering and managerial strategies, the actual cost of which may vary widely depending on what adjustments are made (and there may be a net benefit). In developing cost estimate methodology, it is important to distinguish among different types of regulations and their effects.

Should We Measure Private Costs or Social Costs? Most reporting of the "costs of regulation" has adopted the viewpoint of the regulated industry--measuring the costs of pollution control to the domestic auto or steel industry, or of bottle recycling laws to the beverage industry, or of licensing requirements to the electric utility industry. These costs are real to the firms in question, and in some cases they may also be unprofitable, ineffective, or unfair. Taken alone, however, these costs are not necessarily costs to the national economy or to American society as a whole, which are the primary concern of Government decisions. Several factors distinguish private costs from social costs:

- First, the costs to particular producers may or may not provide useful information about costs to consumers, workers, investors, or even to an industry as a whole.
- Second, they ignore transfer payments--such as costs to one firm of buying pollution control equipment from another--which from an overall point of view may leave the economy just as efficient as it was, or more so.
- Third, they ignore the costs of previous externalities, such as the costs of pollution to the victims, which may be reduced by the firm's expenditures for pollution control.

In short, some regulations impose costs on specific polluters that are also net costs to the overall economy and society, but one cannot make such claims from analysis of industrial compliance costs alone, nor can we derive social costs by simply adding up all the costs claimed by all the regulated firms.

What Are the Purpose and Focus of the Cost Estimates? The issues involved in compliance cost estimation may vary substantially depending on whether the purpose of the analysis is

1. A review of an existing regulation,
2. A projection of the impact of a proposed regulation,
3. A review of the effect of multiple regulations on a particular firm or industry, or
4. A review of the effects of regulations in general (or even of environmental or health and safety regulations in general) on the overall economy.

Most regulatory analyses so far have measured the effects of a proposed regulation. The Vice President's Task Force on regulatory relief has focused on reviewing existing regulations. Current proposals for "regulatory budgets" appear to fall into either the third or fourth category, though it is not yet clear which.

It was frequently unclear during the workshops, and perhaps is unclear generally, which of these four purposes OMB intends to pursue. If OMB identifies the likely approach, then its associated methods and problems can be addressed.

Can Existing Methods Provide Reliable Estimates of the Industrial Compliance Costs of Particular Regulations?

The two main methods in use today to measure the cost of a regulatory requirement are engineering cost estimation and use of a "model plant" to represent common practice in a particular industry or subindustry. Two alternative methods--engineering process models and econometric models--have been suggested, but they have not yet been widely tested for this purpose, they can be costly, and they require a great deal of data.

Another method used more recently is the ad hoc review of the most easily measured costs of regulations that are considered particularly costly; this method is less systematic and complete than the others, but it can be an inexpensive and quick way to address pressing problems.

Existing Methods Raise Technical Problems. All of the existing methods raise questions and problems. Cost estimation methods and assumptions vary substantially among agencies and industries. Many of these variations are legitimately related to differences in factual circumstances or in purpose of the analysis.

Definition of Costs. Studies vary in their definitions of costs. The categories of costs can include direct administrative, capital, and operating costs or can expand to include opportunity costs and changes in management decision and investment patterns, which are harder to measure. Studies also vary in whether they consider incidence of costs to regulated producers, to consumers, or to the economy as a whole (a measure of net efficiency).

Assumptions Vary. Other technical problems include variations in assumptions, and the difficulty of predicting key economic changes. Different cost estimation methods and cost indicators are used in different industries and for different purposes. There is no single "correct" method for all purposes.

Also, different firms, industries, and agencies use substantially different assumptions for key variables such as interest rates, time horizons, depreciation periods, inflation, competitor behavior, price elasticity of demand, and cost of factor inputs. Regulatory cost comparisons may not be possible without standardizing some of these assumptions.

Furthermore, it is difficult to predict future stability or change in regulatory requirements and in vigor of enforcement, although these are important factors in estimating actual compliance costs. Technological innovation is also difficult to predict, and conventional assumptions may underestimate such changes and thus overestimate future costs.

Attribution of Costs. Many costs are difficult to attribute to a particular regulation, especially when there are multiple regulations on the same and related subjects by several agencies and levels of Government, and when compliance costs are influenced by the industry's own actions to increase profits, market share, or favorable image. In principle, the best responses to regulations are those whose costs are so well integrated with the firm's other opportunities and constraints that they are fully joint costs. (This also suggests that any control system which encourages separable accounting of compliance costs may tend to encourage the worst rather than the best responses.) In particular, costs of process changes are far more difficult to attribute to regulations than are end-of-pipe add-ons. Certain administrative overhead expenses, such as an enlarged legal department, may be required by regulation in general but not by any particular regulation.

For similar reasons, it is hard to establish a baseline against which to assess the effect of a regulation, since such a baseline requires difficult assumptions about what would happen in the absence of the regulation. It is also difficult (but important) to determine what costs are due to regulation per se, and which are due to regulatory instability--for instance, when new and unexpected requirements are added after investments have already been made to comply with previous ones, or when regulatory requirements are removed after some firms have sunk control costs into compliance. Furthermore, some costs can be attributed not to a particular regulation but to overlaps, inconsistencies, or redundancies among regulations.

Reliability of Data. Most available data on compliance costs come either from voluntary submissions by the regulated industries, or from estimates developed by the regulatory agencies. Both sources are open to charges of self interest, with industry tending to attribute as many costs as possible to the regulation, and agencies treating compliance costs as the residual after all possible attributions have been made to other factors.

Both industries and agencies tend to ignore--or to make widely divergent assumptions about--cost elements that are widely dispersed or otherwise difficult to measure, such as effects on technological innovation, capital investment, and inflation.

Voluntary submissions may be more apt to come from those firms that feel most burdened by compliance costs, and thus be unrepresentative of the industry as a whole.

"Model plant" analyses may also produce unreliable estimates, either because they are skewed towards "best" or "worst" cases, or because they are unable to represent industries with several different processes or with capital facilities of very different ages and efficiencies.

There is now no system of checking cost estmates made after a regulation has been in effect (ex post estimates) against predictions of costs made before the fact (ex ante estimates). Such a comparison would probably be a useful and important element of a control system.

Comparability. Comparability of data and assumptions could be a serious problem, if OMB tries to set up a comprehensive system of oversight over individual regulatory proposals. A systematic method for comparing regulatory compliance costs of alternative policies could prove difficult and expensive, and the expected benefits might not justify the increased costs.

Ad hoc analysis of particularly burdensome regulations, or of clusters of regulations affecting a particular industry or process, might prove more effective.

Aggregation is another problem that could arise if one wishes to define and regulate an overall level of regulatory cost. It too could be avoided if one wishes only to correct ad hoc problems.

It may prove difficult to aggregate from individual regulatory compliance costs to estimates of regulatory burden in general. This is true partly because of the problems of cost estimation for individual regulations, but also because of the broader problems of joint costs and transfer payments whose benefits to other firms partially offset their costs to the regulated firms. If a central control system for aggregate regulatory costs is desired, therefore, it may have to be based more directly on indicators of aggregate activity--if such can be identified and validated--than on aggregation of cost estimates of individual regulations.

Costs of Analysis. Regulatory analysis itself, especially as a general system, imposes compliance costs--record keeping, data collection, analysis, negotiation among agencies and between agencies and industries, and opportunity costs of prolonged uncertainty about expected outcomes. Careful thought will be necessary as to how detailed an analysis is appropriate to various types of decisions, especially at the level of individual regulatory decisions.

In any event, the designers of the emerging central regulatory control system will soon need to choose which goals the system will pursue, so that effort can be targeted toward solving the problems associated with those goals.

Do Existing Methods Underestimate or Overestimate Compliance Costs?

Costs to Regulated Industry. Regulations not only impose immediate and measurable costs, but also deflect patterns of business decisionmaking. Such deflections are not necessarily costly, but they may be, and they are difficult to quantify and attribute to regulation amid the other forces in the business environment. Factors that would cause existing methods to underestimate costs of regulations to the regulated industry include these:

- Costs of bureaucratic overhead such as enlarged legal, research, and safety departments.
- Costs of lengthened decision processes and heightened uncertainty, in a climate of increased negotiation, potential litigation, and regulatory change.
- Costs of defensive planning, such as premature investments in control technology or other suboptimal investments to comply with regulatory deadlines.
- Costs of diversion of resources, both human and capital, from implementation to documentation, and from product innovation to control innovation.

- Costs of reduction in technological modernization when new plants must meet tighter standards than old ones.

- Costs of price inflation, as regulated firms bid up prices of control technologies.

On the other hand, engineering cost estimation methods and the self-interest of regulated firms will tend to exaggerate the costs that regulations impose. Reasons for overestimation include these:

- Some costs are joint costs of multiple regulations, or of regulations in general, only a fraction of which are due to any one regulation; they may be double counted in some estimates.

- Some costs are imposed not by a regulation itself but by the firms's choice of compliance strategy, which interacts with its pricing, marketing, and other corporate preferences. American auto firms, for instance, chose to invest in different control technology than Swedish firms. The resulting costs may be greater than should be attributed to the regulation per se.

- Ex ante cost estimates consistently overestimate compliance costs by ignoring future process changes and technological innovations. Ex ante estimates usually treat compliance costs as pure add-ons, such as end-of-pipe water treatment plants or stack gas scrubbers. (Some regulations, of course, require use of particular technologies, but many do not.) Once compliance begins, however, firms will usually adjust inputs and processes, and find other ways of reducing their costs. Moreover, a new regulatory constraint can sometimes stimulate a company to evaluate a whole production process, and lead to unforeseen net benefits. Other firms, if they know that regulation will require their competitors to clean up as well, will invest more heavily in control technology innovation and discover new methods of less costly and more efficient environmental control; recent examples include fluidized bed combustion, high-temperature incineration, and pulp and paper chemical recovery.

Costs to Society. Regulations also impose hidden costs on society as a whole, which are difficult to quantify and attribute, and extend beyond cost increases for regulated firms. Factors that lead to underestimation of costs by existing methods include these:

- Costs of overinvestment in control technology relative to its actual benefits, reflected in higher prices and higher interest rates due to diversion of capital investments, and in the opportunity costs of alternative uses of those resources.

- Costs of regulatory friction--such as paperwork, negotiation, uncertainty, and litigation--that exert a drag on a wide range of economic and social activities, especially on small business and entrepreneurial and innovative activities.

However, most estimates of regulatory costs greatly exaggerate their costs to society by focusing narrowly on costs to the regulated industry and extrapolating from these, ignoring offsetting benefits. Factors leading to overestimation of costs to society include these:

- Many costs to regulated firms--perhaps even most of them, in some cases--are simply transfer payments to other sectors of the economy, such as pollution control equipment manufacturers, not net costs in the economy; they may even be stimulating the growth of new and more productive sectors even as they hasten the decline of older and less productive ones.

- Many costs to regulated firms and their customers are also offset by gains to the economy from the costs thereby reduced to the victims of pollution and the taxpayers--costs such as health care, property damage and associated losses in property taxes, and lost productivity. That is, to the extent that environmental regulations are effective, their apparent costs may in fact represent merely correction of previous economic inefficiencies--externalities--rather than real new costs to the economy.

In conclusion, there is great disagreement among informed analysts on whether existing estimation methods overestimate or underestimate compliance costs to the regulated industry and to society. Many factors lead to overestimation or underestimation (listed above) and they are difficult to measure, pervasive, and hard to attribute explicitly to particular regulatory decisions.

It is possible that no satisfactory estimates can be developed for the overall costs of regulatory compliance, because they are beset by so many uncertainties. Yet, some costs can be estimated, and some uncertainties can be reduced, and therefore some regulatory decisions can be improved through judicious analysis and control.

Can the Aggregate Costs of Government Regulation Be Managed through a Regulatory Budget?

Regulatory reform advocates have suggested a "regulatory budget" by which OMB could set annual limits (as it does with the fiscal budget) on the amount of costs each regulatory agency would be allowed to impose by its regulations. Proponents of such a system argue that (1) Federal regulatory activities do impose aggregate costs which should be controlled, (2) as with fiscal budgeting, an overall constraint would force the agencies to set priorities and increase the cost-effectiveness of the regulations they impose, (3) regulations may also impose differential hardships on particular industries or regions, which deserve the attention of a central control system, and (4) a regulatory budgeting approach might require less detailed analysis and intervention by a central control system than would the case-by-case oversight of individual regulations.

As a practical matter, however, neither the concept of a regulatory budget nor measurable indicators of it have yet been demonstrated and validated.

It is not clear how many of Government's regulatory functions would be encompassed by the proposed regulatory budget, but each of the possible answers poses problems. Government regulatory activities are so pervasively intertwined with society's system of rights and exchanges, that it would be hard to isolate and establish individual costs for them.

Another problem is that although the analogy of a "regulatory budget" to the Federal fiscal budget might be attractive to some advocates of the plan, it does not seem valid. One major difference is the absence in the regulatory budget of any means of positive verification of expenditures: as one discussant put it, there are no canceled checks at the end of the year to facilitate an audit. Further, while fiscal costs are incurred solely by Government action, regulatory costs are incurred by nongovernment parties alleging that they are required by Government. Since the nongovernment actors control the response, and thus to a significant degree its costliness, the cost data are beyond clear Government control, and are subject to strategic behavior and exaggerated claims by parties wishing to minimize or thwart Government action. In short, a fiscal budget has a single client and tangible, auditable flows of money; a regulatory budget has neither.

Setting the level of a budget for annual environmental regulation costs would be a legislative function, just as fiscal budget levels are set by Congressional appropriations. Even here the fiscal analogy must be used cautiously, however, for even if Congress did set regulatory budget levels they might be invalidated where they conflicted with statutory requirements.

One purpose that has been advanced is that a regulatory budget would enhance overall economic efficiency. It is not clear that regulatory budgeting would necessarily produce greater efficiency even if it were fully established. Fiscal budgeting is heavily influenced by political factors within the agencies and in the Congress, and this could happen with regulatory budgeting as well; besides, any new documentation system compounds the administrative inefficiencies of documentation and justification as well.

Furthermore, if the regulations affect only the profitability of the regulated industry, and not the efficiency of the economy as a whole, then one has only a special pleading rather than a general justification for regulatory budgeting.

If one seeks to develop the regulatory budget by aggregating information about individual regulations, one must deal with all the problems of micro-level cost/benefit analysis, such as attribution of joint costs, transfer payments, unreliability of data, difficulty of establishing baselines, and problems associated with aggregation itself.

Some analysts have suggested that regulatory budgeting might be effective by forcing an annual regulatory review process, even if it proved intractable as a substantive analytical or control procedure. This could be true, but it would not be a regulatory budget in any conventional meaning of a budget;

it would be simply an administrative arrangement in which regulatory decisionmaking authority was somehow shared bettween each operating agency and OMB. Such an arrangement would be justified only if it were kept politically accountable within the intent of the agencies' statutory mandates, and if it provided benefits greater than the increased transaction costs associated with negotiation and shared authority.

It is not clear, as a practical matter, that the overall level of regulatory compliance costs is really the issue that concerns most of the American public or even the regulated industries themselves. The overall level is a useful symbol for organizing diverse constituencies to press for regulatory reform, but specific regulations really motivate each constituency. For some constituencies, such as primary extraction and processing industries, it is pollution control and occupational safety rules; for others, such as the construction and fabrication industries, it is perhaps occupational safety and labor and affirmative action regulations; for universities, it is affirmative action, women's athletics, barrier-free access, and faculty time accounting requirements (the latter imposed by OMB itself). Most constituencies probably gain from and approve of many regulations even though they feel burdened by others. Perhaps the only issues on which all agree are the desire to slow the rate of regulatory change, and to eliminate, on an ad hoc basis, regulatory inconsistencies, redundancies, and absurdities.

OMB control of the overall level of regulation will not provide direct solutions to these more specific complaints, and indeed it might simply divert effort away from them toward the creation of a new budgeting system. This would be unfortunate.

What Lessons Does This Discussion Offer for the Design of a Central Control System?

Everyone agrees that some environmental regulations are poorly designed and could benefit from cost-reducing changes. It is less generally agreed what changes in which regulations would be desired, and not at all agreed that the overall level of regulation is an important problem. Most of the discussants were sympathetic to the need to ameliorate some of the compliance costs imposed by environmental regulations, but they remain quite skeptical of current proposals for comprehensive central regulatory control systems. This skepticism applies to "cookbooks," or detailed procedures for comparative cost/benefit analysis of individual regulations, and to the notion of a regulatory budget.

OMB seems to feel that the mandate to implement such a system is now a given, and that it must therefore get started on something, and in some direction, though it does not yet have a clear rationale for what exactly is required. Ironically, in this mandate OMB is itself becoming a regulatory agency, regulating the other regulators; and in its impulse to do something without knowing quite what, it is flirting with exactly the mentality of a new regulatory agency that has created many of our current problems of regulatory compliance costs. It behooves OMB, therefore, to move cautiously in developing case-by-case understanding of the problems, analytical procedures and methods, and possible solutions before mandating a new full-blown system, lest it simply reinvent existing problems at a higher level of review.

Past experience suggests that while good analyses can improve Government decisions, most new analytical *systems* that have been mandated have failed to achieve their intended purposes; and in the process they have added new layers of bureaucracy, paperwork, and administrative inefficiency. Benefit/cost analysis of water projects, for example, has given birth to a sizable economic literature and has undoubtedly stopped the construction of some egregiously poor projects, but the bulk of the water development continues, with the simple addition of new layers of paperwork justifications.

The same is true of Management By Objectives (MBO) in the 1970s, and of attempts to create comprehensive information systems generally, most of which have failed and wasted resources. Probably the only new major Government-wide analytical system that has stabilized and survived is the preparation of environmental impact statements (EISs), and this one has survived not because it produces good analysis (though it sometimes does, it often does not), but because it opens new avenues for influence on decisions by affected parties, through public involvement procedures and judicial review.

On the other hand, good analyses of particular proposals can often help to stop egregiously bad proposals and to encourage unusually promising ones.

OMB does have at least three promising roles open to it in regulatory reform, roles which it has played in the past and which could aid substantially in current regulatory issues. First, it can serve as an *advocate for efficiency*, by working to improve both the administrative efficiency of U.S. Government operations, and the social efficiency of its programs. This role is strongly consistent with the professional ideals of OMB staff, although it is not always consistent with the Agency's practical political reality as confidential staff to the President. Much could be done to improve regulation if OMB were simply to work case by case with the agencies in adjusting the most egregiously inefficient regulations, without any overall paperwork systems.

Second, OMB can serve as the "*necessary enemy*" of the agencies, challenging proposals or programs based on established assumptions, methods, and priorities that may have outlived their validity. By doing so it aids innovators within the agencies in achieving better results. All human organizations gradually fall into stable patterns, and most require external challenges to stimulate re-examination of such patterns; OMB is institutionally well placed to raise such questions about regulations, as it does already about expenditures, if it can develop sufficient analytical competence and avoid spreading its effort too thinly.

Third, OMB can serve as an *advocate for methodological improvement*, both within and beyond Government, as it has done frequently in the past in such areas as program budgeting and benefit/cost analysis. The mandatory systems associated with these labels have not been especially effective, but the analytical methods have improved, thanks in part to OMB's encouragement.

The following suggestions may help OMB meet its responsibility under Executive Order 12291, while clearly recognizing the difficulties and complexities raised in the workshop:

1. Start by discriminating among different types of regulations and their associated cost patterns--such as procedural and reporting requirements vs. mandatory technologies vs. performance standards--in order to select priorities for special analyses.

2. Start with solid cases and build outward gradually toward the harder ones: build a control system incrementally from real pieces, not overnight from an untested concept. OMB can usefully work in the direction of a central control system without necessarily expecting to arrive at a full-blown regulatory budget; and if in the process it can help weed out a few of the most inconsistent, incomprehensible, ineffective, or inefficient requirements, it may achieve all that should be expected.

3. Recognize and encourage the clash of adversary analyses: The results will be far more useful than any officially sanctioned "cookbook." This requires also a willingness to keep the analytical process visibly accessible to the interested public, a role somewhat less comfortable to OMB but one which has a high payoff in legitimizing the results.

4. In analyzing proposals either for new regulations or for changes in existing ones, focus analytical efforts on the differences among alternatives, including always the option of no change from the regulatory status quo. Sophisticated cost estimation for a single proposal is of little use for decisions without equally sophisticated analysis of its benefits and comparison of these with the costs and benefits of alternative means to the same end, and industrial compliance costs alone are not an adequate or legitimate basis for public regulatory decisions. The Council on Environmental Quality regulations for implementing the procedural provisions of the National Environmental Policy Act, and the EIS methodological literature, provide useful discussion of some of these analytical issues.

5. Encourage scholarly thought and experimentation on broader or longer term questions, such as the relative merits of national minimum standards vs. regionally differentiated standards, regulatory budget proposals, and other new alternatives to burdensome forms of regulation.

II. LIST OF WORKSHOP PARTICIPANTS

NSF WORKSHOP ON EFFECTS OF ENVIRONMENTAL REGULATION ON INDUSTRIAL COMPLIANCE COSTS AND TECHNOLOGICAL INNOVATION

September 10-11, 1981

Category	Name	Affiliation
Authors	Christopher T. Hill	MIT Center for Policy Alternatives
	Raymond J. Kopp	Resources for the Future
	Paul R. Portney	Resources for the Future
	Victoria M. Potter	Consultant
	Joseph A. Vasquez, Jr.	ICF, Inc.
	David E. Wojick	Adams & Wojick Associates
Reviewers	Richard N.L. Andrews	University of North Carolina
	Robert W. Crandall	Brookings Institution
	Leslie Dach	National Audubon Society
	George C. Eads	Rand Corporation
	Khristine Hall	Environmental Defense Fund
	Robert M. Heine	Conoco Inc.
	Joe N. Nay	Performance Development Institute
	Carl W. Noller	U.S. Chamber of Commerce
	Robert Percival	Environmental Defense Fund
	Michael A. Pierle	Monsanto Company
	Larry E. Ruff	Synthetic Fuels Corporation
Others	Warren Easley	Monsanto Company
	James C. Hersey	Kappa Systems, Inc.
	Van E. Langley	Conoco Inc.
	Jeffrey A. Kolb	Environmental Protection Agency
	Richard A. Tropp	Environmental Protection Agency
	Gail Updegraff	Department of Agriculture
	Jonathan B. Weiss	Department of Transportation
	Barbara A. Cho	Office of Management and Budget
	Edward H. Clarke	
	Art Fraas	
	Brian Mannix	
	Mahesh K. Podar	
	Jim J. Tozzi	
	John Marcum	Office of Science & Technology Policy
	Denis Prager	
	Harvey Averch	National Science Foundation
	Alden S. Dean	
	Geoffrey M. Holdridge	
	Frank L. Huband	
	Leonard L. Lederman	
	Richard E. Morrison	
	Trudy L. Solomon	
	Robert R. Trumble	

III. SELECTED QUOTATIONS FROM THE WORKSHOP PROCEEDINGS

NOTE: This selection of quotes from the workshop proceedings gives a flavor of some of the main issues, participants, and subjects discussed during the workshop.

The purpose of the workshop is to bring together individuals with diverse viewpoints and experiences, hoping that the ensuing discussion will both illuminate the areas of general agreement and sharpen our understanding of the areas of disagreement. (Huband)

What I see evolving is a central control system on regulations, [which] is being debated in this town. I think it will continue to be debated over a number of years....

Assuming that we are going to have a control system, we would like to see, as a result of these and other papers, some idea of how and what is the current status and what can be done under current methodologies to provide a basis for assessing the impacts of regulation. (Tozzi)

The main objective of my paper is to address the contribution of technological innovation and learning to regulatory compliance cost. A secondary objective is to look at what our understanding of innovation and learning might contribute to understanding how better to regulate, assuming that in the real world in which we live we will continue to regulate in some way....

There has been a presumption in most of the literature that regulatory cost analysis is pretty straightforward. It might be tedious, it might be expensive, but it's pretty straightforward. We know how to do it. And the real challenge is on the benefit side. Most of the literature has had to do with how the scientific problems are so terribly complicated on the benefit side. I believe that if we look at the cost side, we will find that there are problems on that side as well.

I would not recommend that we continue to use engineering cost estimation until NSF has funded a 5-year program to improve methodology. That wouldn't help OMB or the world in the short term. (Hill)

We begin our paper by asking, why in the world do you want to estimate the cost of complying with Federal regulations anyway? And we discuss what we see as the most important reasons:

(1) Estimates of the cost of particular regulations are a precondition if we're going to do any kind of benefit/ cost analysis, cost-effectiveness analysis, or regulatory impact analysis, if that's going to be required as it is in Executive Order 12291. So, if you're going to do that kind of analysis of regulations, obviously you're going to need some estimate of the costs that go along with the regulation.

(2) The second reason has to do with their use in the past and their prospective use in the future as inputs to macro studies of the impacts of regulations.

(3) The third reason we need to know something about the cost of complying with Federal regulations is that they're essential if we're going to make some regulatory budget approach actually work--something about which I am skeptical....

There seems to be a lot of enthusiasm about pursuing the idea further. If we even want to pursue the idea further, we're going to need estimates of the cost of compliance....

Most of the surveys have to do with ex post costs. In other words, after the fact, how much did you spend last year or 2 or 3 years ago on environmental regulations. If we want to do benefit/cost analysis of prospective regulations, or to examine the distributional or macroeconomic effects of potential regulations, then we need ex ante estimates, or estimates of the costs of proposed regulations before the fact. (Portney)

What is the thesis of our paper? Why did we choose process models and econometric models as vehicles for future compliance cost estimation?... We were looking for structures. We reviewed what had been done in the past on compliance costs. It was a hodgepodge, a bag of various different types of methodologies which were really going to be tailored for individual kinds of regulations. But we were looking for a structure, some way to organize compliance cost estimation around a basic structure. (Kopp)

I have spent most of my time looking at the benefit side, but what strikes me here is the same thing that struck me there, how little empirical, numerical data there are to support any exact numerical estimate of costs or benefits. And I think that's the important message to come out of these papers, because at the same time there is a lot of effort politically in regulatory reform legislation to require some sort of detailed cost/benefit analysis....

It's incumbent on people who spend their research time in this area to point out to a lot of the politicians who are grasping at what is apparently a very rational approach, that we really don't have the methodological experience to implement it in an appropriate fashion. That message doesn't seem to be getting across. (Dach)

The paper I developed was designed primarily to provide some information based on a case study, in order to evaluate some of the issues raised by the other authors....I examined the emissions control regulations that were promulgated over the last 10 years, [which] regulate emissions from automobiles....We tried to look at the effect of Federal emissions control regulations on technical innovation in the automobile industry....

We used a proxy for technological innovation, which was manufacturers' investment in research and development for emissions control devices. I do recognize that there may be some people who will argue that that's not an appropriate proxy, but at least I assumed it was a good start. (Vasquez)

I want to remind the group that regulation can inhibit innovation. There is an undercurrent here that OMB should tell EPA and DOT how to do cost analysis so it will all be consistent, and so the mythical decisionmaker will have a uniform basis on which to decide.

But this control mechanism is a new kind of Government regulation, and we don't know how to do the analysis. And it's clear that if a cost analysis regulation were established today prescribing how these studies ought to be done, it would be modeled after engineering cost estimation. We know that for lots of reasons...engineering cost estimation isn't the right way to go. It's not the only wrong way, but it isn't the right way, and we need room for experimentation and learning on how to do these things. (Hill)

One key point is that there does seem to be a great variation among cost estimation methods in common use.

The question is, can some of these be ruled out in favor of a small number of better ones? Can and should OMB sponsor any single method or cookbook, in order to achieve some kind of consistency and comparability?...Or would the cure...in some cases at least be worse than the disease? (Andrews)

There is confusion in writing a 3,000-page document, with an enormous number of references. There is an enormous cost there. You all see it when a new, big regulation comes out; millions of dollars are spent just by people trying to figure out what it means....

Why do people want less regulation? I don't think its a perception that their ox is being gored; it's a general perception that regulations are costing too much. Most people couldn't name a regulation if you asked them to....But "intrusion" is the word. People have just become aware of the fact that they're being boxed in by government rules....People have become aware of an enormous increase in Federal power, not through spending, and not through actions of agencies, but through regulating people. (Wojick)

I have heard two theories of why we should have a regulatory budget, and what it should focus on:

(1) We want to aggregate regulatory costs because the total demands imposed by Government on the economy, not only the tax burden but the burden of regulations, are getting very large and worrisome in the aggregate. And we ought to have an idea of what that burden is.

(2) The other theory is that we should look at individual sectors that are being hit with a particularly worrisome burden. The one that comes to mind is the automobile industry, where capital expenditures are a problem. The electronic utilities are another case. (Mannix)

I don't think you necessarily would get more efficiency with a regulatory budget. But the proponents would say, look, if you gave them a budget so that they couldn't regulate till the cows came home, in other words if you constrained their appetites somehow, that they'd pick only the very best regulations. (Portney)

So far we've been talking about whether or not we should do regulatory budgets. Assuming for a moment that we are required by the Congress to do regulatory budgets, I'm not sure we can do a regulatory budget right now. (Podar)

If you don't ask the right questions to start with, you're going to have a total which is very misleading. I would insist that if you're going to do that, you should at a minimum address the indirect costs and the benefits of regulations. [If this is impossible,] then my argument would be, don't do it. (Hill)

I would suggest that if we really want to get some action with respect to a regulatory cost accounting program or budget, then we need a directive from OMB that says something like, "We would like you to start moving toward regulatory cost accounting programs." This would force us to work more seriously trying to figure out which costs are going to be included, and which estimation methods to use. (Updegraff)

It seems to me that what industry is looking for is better efficiency through lack of duplication. The agencies can each go their own way in regulation, and there is now no general management control in that process....

You must get going....If we agree, as the public tells us, that we are overregulating, then there has to be a start somewhere. Somebody has to take leadership and...take that first step. (Pierle)

I think it's inevitable that something will be done to establish control over regulatory costs. I would hope to see, as much as possible, an equivalent concern for the methods and mechanisms for addressing the benefits of regulation, and for what those mean for the policy decisions, and an equivalent concern for the total impact on specific sectors on the benefits side. (Hill)

I think this has been a useful exercise. We all realize how much we don't know yet, and therefore how much is left to be learned. (Morrison)

THE EFFECTS OF TECHNOLOGICAL INNOVATION AND REGULATORY DESIGN ON REGULATORY COMPLIANCE COSTS

by

Christopher T. Hill
Center for Policy Alternatives
Massachusetts Institute of Technology
Cambridge, Mass.

CONTENTS

Page

1.0 Introduction

1.1 Background 27
1.2 Purpose, Approach, and Scope 28
1.3 Organization of This Paper 29

2.0 The Static Analysis of Firm-Level Costs 30

2.1 Engineering Cost Analysis for Compliance Costs 30

2.1.1 Capital Cost Estimates 32
2.1.2 Operating Cost Estimates 36
2.1.3 Total Annualized Costs 36

2.2 Other Firm Level Costs 38

3.0 The Dynamic Analysis of Firm Level Costs: Technological Innovation and Change 39

3.1 The Effects of Learning and Experience on Compliance Costs 40

3.1.1 The Nature of the Learning Curve 40
3.1.2 Learning and Regulatory Compliance 41

3.2 Technological Innovation and Compliance Costs 42

3.2.1 The Nature and Sources of Technological Innovation 42
3.2.2 The Interactions of Technological Innovation and Regulation 43
3.2.3 Technological Innnovation and Compliance Costs: Some Examples 44
3.2.4 Technology-Forcing Regulation 46

3.3 The Effect of Regulatory Demand on the Cost of Process Inputs and Technologies 47
3.4 The Incompatibility of Learning and Technological Innovation Strategies 48
3.5 Resolving the Cost-Reducing and Cost-Increasing Effects of Innovation 50

4.0 The Analysis of Industry-Level Costs 50

4.1 Sources of Complicance Cost Data 50
4.2 Aggregating Costs Across Firms 52

4.2.1 Projecting Compliance Levels 52
4.2.2 Model Plants and Industry Diversity 53
4.2.3 Quantity Discounts 53

Page

5.0 Other Considerations in Cost Analysis 53

  5.1 Selecting an Appropriate Baseline for Comparison 53
  5.2 Spillovers to Other Regulations 54
  5.3 The Treatment of Joint Costs for Compliance and Production 55
  5.4 Social Versus Private Costs 55

6.0 The Effects of Regulatory Design on Compliance Costs 56

  6.1 Command and Control Regulations 56

    6.1.1 Institutional Aspects of Command and Control Regulations 56
    6.1.2 Structural Details of Command and Control Regulations 58

  6.2 Economic Incentive Regulation 61

7.0 Findings and Conclusions 62

  7.1 Regulatory Cost Analysis 62
  7.2 Research Needs 63

References Cited 66

1.0 Introduction

1.1 Background

The last 6 years have witnessed an explosive growth in the demand for economic analysis of Government regulatory programs. While economic analysis has been applied in a variety of regulatory contexts, its most controversial use has been in the area of the regulation of environmental, safety, and health hazards. As the costs of the environmental, health and safety laws adopted or strengthened in the 1960s and early 1970s have become more apparent, more and more attention has been focused on the costs they impose on industry and on the public.

Within the Federal Government the formal requirements for economic analysis of regulation have had two origins. First, several of the environmental statutes, including parts of the Clean Air Act, the Federal Water Pollution Control Act, and the Toxic Substances Control Act, require that agencies consider the economic implications of a regulation as part of the standard-setting process. Second, for those agencies and regulatory regimes that do not require economic analysis as part of the decision process, a series of Presidential executive orders has established ever more rigorous requirements for regulatory analysis. Under President Ford, Executive Order 11821 established a requirement that agencies consider the "inflationary impact" of proposed regulatory decisions. Later, President Carter in Executive Order 12044 extended and expanded this requirement to require a draft regulatory analysis of all significant regulations. Most recently, under Executive Order 12291, promulgated on February 17, 1981, President Reagan has required that where possible under the law all significant new regulations must meet a cost/benefit test.

As the requirements for economic analysis of regulations have become more stringent and quantitative, and as the policy decisions of regulators have been made more dependent on the outcomes of economic analysis, the need has emerged to improve the quality of regulatory analysis to be sure that it is done both fairly and accurately. Clearly, a regulatory cost analysis intended to support a discussion of the inflationary impact of a proposed regulation does not need to be as accurate as one intended to support a judgment of the amount by which the marginal benefits of a proposed regulation exceed its marginal costs. In this context, of course, accuracy refers not only to numerical soundness but to conceptual and methodological soundness as well.

The author wishes to thank Richard A. Andrews for valuable contributions and Jan L. Cassin for information gathering and secretarial assistance. He is also appreciative of the many helpful comments offered by Richard N.L. Andrews, Leslie Dach, George C. Eads, Khristine C. Hall, John A. Hansen, George R. Heaton, J. Herbert Hollomon, Burton H. Klein, Carl W. Noller, Charles M. Overby, Robert Percival, Michael A. Pierle, David Rosoff, Larry E. Ruff, and James M. Utterback.

Most regulatory analyses of proposed environmental regulations have stressed the cost side of the cost/benefit evaluation. On the other hand, the focus of the theoretical and conceptual literature on environmental cost/benefit analysis has been on methodologies for analyzing the benefits of regulation and on the policy implications of the use of cost/benefit analysis in decisionmaking. The tacit assumption is that cost analysis per se is reasonably well in hand. However, this paper will argue that most regulatory cost analyses are based on complex but naive static models of the responses of firms to changes in their environments, that were not intended for this purpose and are the cause of significant error. It finds that the analysis of the cost of regulation is in considerable disarray and that the methodologies must be improved if such analyses are to be reliable and credible.

1.2 Purpose, Approach, and Scope

The purposes of this paper are to describe and assess the current practice of regulatory cost analysis, to show how current practice systematically overstates regulatory costs, and to identify opportunities to improve that practice. It focuses on the contributions of technological innovation and change to reducing the costs borne by regulated industries. A second purpose is to describe how the detailed design of command and control and economic incentive regulatory programs can influence corporate technological responses and thus the costs ultimately paid by industry and the public.

This paper is focused on the prospective analysis of proposed regulations, rather than on the retrospective analysis of regulations that have already been put into effect. Such prospective, or ex ante, analysis is the problem faced by a regulatory analyst in an agency today. As compared with ex post evaluation, in ex ante analysis there is greater uncertainty about the responses of industry, both in terms of compliance and in terms of technological innovation and change, as well as greater uncertainty about the costs that will ultimately be paid.

A review and analysis of research and information from existing sources is the basis for this paper. It draws on academic literature, earlier studies funded by Federal regulatory agencies, and the general literature on technological innovation and learning. A number of its assertions are based on more general arguments about innovative behavior. Clearly, there is need for additional modeling, for empirical studies of existing regulations, and for experiments in regulatory program design to improve our understanding of the regulatory process and the associated industrial response.

This paper is concerned primarily with command and control regulations of the type adopted in the United States since around 1965. It is concerned with regulation of the processes firms use rather than of the products they make. In particular, it focuses on requirements typified by those under the Clean Air Act, the Clear Water Act, and the Resource Conservation and Recovery Act. It does not address product regulations imposed by the Food, Drug, and Cosmetic Act, the Toxic Substances Control Act,* or the Consumer

---

* TSCA gives EPA authority to regulate industrial processes and practices, although the actions taken to date under TSCA have not been of this type.

Product Safety Act; nor is it concerned with regulations under the Occupational Safety and Health Act, although much of the analytic content applies to them.

We are concerned here only with methods for analyzing the costs of regulatory programs. The analysis of the benefits of environmental regulation has been addressed in a number of other studies and reports. For recent reviews, the reader is referred to works by Freeman (1979), Ashford, Hill, et al. (1980), and CPA (1981), who report on the conceptual difficulties, complexities, and uncertainties of the benefits side of a regulatory analysis. Benefits analyses pose challenges that are at least as great as any faced by a cost-side analyst, and when chronic health hazards are of concern, the challenges are much greater. While we focus here on the cost side, we must keep in mind the importance of improving methods of benefits analysis.

This paper also does not consider the appropriateness, problems, or costs to society of using the cost/benefit approach for making public choice. Kelman (1981) points out that the cost/benefit analysis approach reflects a utilitarian view of social choice that is no longer in favor with moral philosophers, and that it threatens, through monetization of certain nonmarket values, the foundations of social behavior. Similarly, Schultz and Kneese (1981) show how cost/benefit analysis addresses only a special case of utilitarianism and does not address other legitimate concerns of society, such as protection of individual rights. On a more instrumental level, use of cost/benefit analysis may replicate in the public sector the problems that narrow financial analysis brings to private firms, a subject I have recently explored elsewhere. (Hill, 1981) Thus, while this paper recognizes the current role and importance of cost/benefit analysis in regulatory decision-making, this should not be taken as agreement that cost/benefit analysis is the preferred method for analyzing public choices.

The first goal of any environmental regulatory program is to achieve a reduction in the risks to human life, health and the natural environment posed by environmental hazards. However, there are many ways to achieve this social goal, and each may impose different costs on industry and on the public and may create different problems for regulatory cost analysis. There is no social advantage in requiring industry to spend more than necessary to comply with a socially imposed regulatory requirement, and it is in everyone's interest to seek low-cost ways to achieve a regulatory goal consonant with achieving other social goals such as procedural fairness, equity, and security. Section 6 of this paper examines the consequences for innovation and for regulatory costs of the detailed design of both command and control regulations and some of the more popular alternatives for social control of risks, especially economic incentive approaches.

1.3 Organization of This Paper

Sections 2 and 3 of this paper address the static and dynamic modes of analysis of the costs imposed on individual firms by proposed environmental regulatory requirements. The static mode, addressed in section 2, is concerned with how cost engineers and financial analysts ordinarily look at the costs of compliance and at the other costs imposed on the firm by regulation.

Section 3 examines the dynamic mode of analysis of costs at the firm level, including technological innovation, learning, and the effects of changes in the demand for inputs. Section 4 is concerned with aggregating firm-level costs to an entire industry affected by regulation. Section 5 addresses how interactions among regulatory programs complicate regulatory cost analysis and mentions briefly the relationships between private, firm-level costs and total social costs. Section 6 addresses the effects of regulatory design on compliance costs for command and control and economic incentive regulations. Section 7 presents some findings and conclusions about the process of regulatory cost analysis under the current circumstances and highlights research opportunities for improving it.

2.0 The Static Analysis of Firm-Level Costs

Projecting the costs of a proposed regulation at the firm level is usually approached using the standard methods of engineering cost analysis. One estimates the direct private costs faced by a firm for compliance and other purposes. Direct private costs are costs that affect the profit and loss statement of the regulated company. Since they are based on detailed descriptions and disaggregations of a process flow sheet, such engineering cost estimates are often highly detailed, and are often wrong, especially because they are unable to consider the potential contributions of the new control technology and new process technology, which is so often at the heart of the responses of industry to regulation. To provide a basis for understanding the impact of new technology in regulatory analysis, this section examines the engineering cost analysis tradition in some detail. Section 3 then examines technological innovation and dynamic analysis of firm-level costs.

2.1 Engineering Cost Analysis for Compliance Costs

The well-established tradition of engineering cost analysis for financial decisionmaking by private firms has been adopted essentially without change for regulatory cost analysis. Broadly speaking, two functions are involved: engineering cost estimation, which entails estimating the fixed and variable costs associated with purchase and operation of specific items of plant and equipment, and engineering economics, which entails analyzing the implications for the firm of an investment choice from among the alternative items of plant and equipment whose costs have been estimated.

Engineering economics, also known as managerial economics, engineering economy, and project financial analysis, is a well-developed field, as attested by the existence of many standardized texts. See, for example, Grant, Ierson, and Leavenworth (1976); Riggs (1977); Taylor (1980); White, Agee, and Case (1977); DeGarmo, Canada, and Sullivan (1979); and Peters and Timmerhaus (1980). For the most part, these texts are concerned with the tools used to assess the implications of a particular schedule of costs for the firm. They examine at great length the implications of that cost schedule, and of such matters as taxes, the financial structure of the firm, depreciation rules, and equipment life for the firm's cash flow and profit and loss statement. Except for brief chapters on public investments, these texts assume that (1) the decisionmaking unit is a private firm, (2) the firm is a profit maximizer, or tries to accomplish its objectives at the least cost, (3) the firm knows its future cost and income streams with certainty or can attach specifiable probability distributions to those streams, and (4) the firm does not consider the external costs of its actions when making decisions.

The cost inputs to the engineering economic analysis are provided by the cost engineer or the engineering cost estimator. Standard references in this field are texts by Ostwald (1974), Park (1973), and Weaver, Bauman, and Heneghan (1963). Helpful recent papers on cost estimation for process equipment have been published by Cran (1981) and Desai (1981). Standard approaches to cost estimation have been elaborated in some detail for pollution control devices in general by Uhl (1979) and for air pollution control devices installed pursuant to the New Source Performance Standards provisions of the Clean Air Act by PEDCo Environmental, Inc. (1979). Vatavuk and Neveril (1980) have published a series of papers on cost estimation for air pollution control devices.

Using a variety of techniques developed over the years, the cost estimator makes estimates of the capital and operating costs arising from the adoption of specified items of equipment, either for ordinary production or for compliance with regulatory requirements.* Cost estimation is relatively straightforward for so-called "end-of-pipe" approaches to compliance, because they involve attaching a separate piece of equipment of established design to a production facility to recover its effluents or render them unobjectionable under the law. In general, cost estimation is more difficult when regulations are met through process modifications because such modifications are not known in advance, and because allocation of joint costs and benefits to production and environmental control becomes an issue.**

It is customary in cost estimation for regulatory compliance to use a "model plant" approach, in which one estimates the incremental costs of compliance for hypothetical plants that typify those expected to be built, or that exist in the industry in question. These hypothetical plants do not take into account any special costs or opportunities associated with local conditions. It is also customary to treat income from the recovery of byproducts and cost reductions from improvements in the productivities of labor or resource inputs as offsets to compliance costs rather than as benefits of the regulation.

Cost estimation has taken on a specific format closely allied with the economic and accounting principles of business firms. These principles are appropriate for analyzing costs of compliance for a particular firm, but they can not address such matters as the contributions of firms outside the industry, technological change, and the difficult-to-predict dynamic variables that influence industry-wide compliance costs in the long run. It is important to recognize that regulatory cost analysis is not being carried out for an individual firm that will have to decide how to comply, but rather by society, which is trying to decide whether and how to change the behavior of all firms in the industry to attain the most effective and equitable allocation of the Nation's resources overall.

---

* Typically, design and cost estimation are separate functions, which inhibits feedback from cost implications to design changes.

** This paper does not address the question of creating incentives for accurate cost estimation. See White (1981).

The following subsections briefly describe the process of engineering cost estimation in order to provide a basis for discussing some of its limitations and inherent biases when used in regulatory analysis. For more specific procedures and input data, the reader is referred to the texts, articles, and reports mentioned above. For example, Peters and Timmerhaus (1980) offer an extensive bibliography of practical articles on cost estimation.

2.1.1 Capital Cost Estimates

It is customary to make cost estimates for engineering projects at five levels, each level representing a higher accuracy and a more firm commitment to action by the decisionmaker. Table 1, from Uhl (1979), shows the expected accuracy for and the appropriate decisions to be based on the five levels of estimates. It should be emphasized that the accuracy estimates apply for "well-established" technologies and that ranges may be wider for newer technologies. Table 1 also summarizes the kinds of information needed to perform cost estimates at each of the five levels.

The resources required to perform cost analyses at the more accurate levels grow rapidly. Table 2 shows estimates of the costs of performing cost estimates at various levels for single process plants in 1979. These are rough estimates that are based on an original source dating from 1964, so they must be viewed with caution. They apply to well-known technologies, and the costs of estimating costs would be higher for new technologies. Furthermore, compliance cost analysis for an industry of several plants would cost more, since several model plants must be described and cost estimates tailored for each one. Thus, these data highlight the fact that making credible cost estimates can cost a substantial amount of money.

Regulatory cost analysis is nearly always based on "study" estimates. The next more accurate level, the "preliminary" estimate, requires specification of site-related information that the model plant approach, based on hypothetical typical plants abstracted from local conditions, can not accommodate. For purposes of estimating costs for the "Background Information Document" for a New Source Performance Standard under the Clean Air Act, PEDCo (1979) states that a "study" estimate is adequate. The implications of this practice are that, first, such an estimate will typically cost $10,000 to $25,000 to make for one well-known end-of-the-pipe control technology, and second, a cost/benefit ratio based on such a calculation can never be more accurate than that, with a bias toward overstatement.

TABLE 1. DEFINITION OF FIVE BASIC TYPES OF ESTIMATES OF TOTAL PLANT COST

Type[a] (Each has several designations)	Characteristics	Purpose	Usual Reliability[b]
1. Order-of-magnitude[c] Ratio	Rapid. Very rough.	Preliminary indication. Check on result by more detailed method.	About + 30% - 60%
2. Study[c] (commonly a so-called factored estimate)	Requires flow diagram, material and energy balance, type and size equipment.	For generalized evaluations. Guidance for further investigation. Basis for process selection. R&D guidance.	± 30%
3. Preliminary[c] Budget Authorization	In addition to above, surveys and some engineering of foundations, transportation facilities, buildings, structures, lighting, etc.	Basis for decision to undertake detailed engineering. Sometimes basis for budget authorization. Can be for generalized evaluation, but usually for site-specific installation.	± 20%
4. Definitive Project Control	More detailed engineering, but usually short of complete specifications and working drawings. Requires experienced estimating organization and substantial outlay.	Sometimes the basis for budget authorization. Provides improved estimate of project to be built. For site-specific installations.	± 10%
5. Detailed Firm Contractor's	Complete site surveys, specifications, working drawings.	Made to control cost of project being built. For site-specific installations.	± 5%

[a] This is a representative and comprehensive list of the types of estimates for total plant cost. Other such lists differ in the number of estimate types and their descriptions.

[b] These apply for well established technologies. For newer technologies, the ranges may be wider, particularly for the first three types of estimates.

[c] The first three types of estimates are also termed "conceptual estimates."

Source: Uhl (1979)

TABLE 2. TYPICAL COST RANGES
FOR PRODUCING CAPITAL COST ESTIMATES[a]

Type of Estimate	Total Plant Cost		
	Less than $2 million	$2 million to $10 million	10 million to $100 million
Order-of-Magnitude	$ 2,000 - 10,000	$ 5,000 - 20,000	$ 8,000 - 25,000
Study	$ 4,000 - 12,000	$10,000 - 24,000	$16,000 - 32,000
Preliminary	$12,000 - 30,000	$24,000 - 50,000	$40,000 - 80,000
Definitive	$20,000 - 50,000	$ 50,000 - 100,000	$ 90,000 - 200,000

[a] The figures are intended only as a rough guide. The range of activities covered by these costs can be considerable; depending on the type of estimate, it can include engineering, drafting, surveys, travel, copying, communication, office overhead, besides the actual cost analysis.

Source: Uhl (1979)

To make a detailed equipment cost estimates it is convenient to divide the expenditures for capital equipment into three broad groups:

> "Group I includes items with standard designs and sizes, such as pumps, tanks, fans, and some air pollution control devices. Group II includes partially standardized equipment, such as heat, exchangers, clarifiers, and fabric filters. Group III consists of equipment with special design or size requirements, such as distillation columns, pressure vessels, reactors, and pollution control equipment for large systems.
>
> Price lists for Group I equipment are available from fabricators or vendors, and Group II equipment costs can usually be calculated by a correlation analysis. No standard price lists, however, are available for Group III equipment; after preliminary process criteria are established, price estimates should be secured from several sources." (PEDCo., 1979, p. 40)

The uncertainties in component costs can be expected to be greatest for Group III and smallest for Group I. Unfortunately, for any regulation that requires significant control expenditures, Group III costs are likely to dominate the total costs, and thus, the uncertainties. Furthermore, Group III costs are the most sensitive to the local conditions that are omitted from the "study" estimates used in regulatory analysis. As a consequence, capital equipment cost estimates for environmental controls are likely to be highly uncertain, even for end-of-pipe devices of known design.

The capital investment cost of a new project in industry involves not only expenditures for equipment but also a wide range of auxiliary capitalized expenditures for such things as installation costs, services and utilities, and site improvements. In addition, capital costs are conventionally defined to include property taxes and insurance. In the engineering cost analysis approach, rules of thumb have been developed for assigning these auxiliary investment costs to a project. Many articles featuring different allocation rules have been published. In a recent article, Cran (1981) reported that a factor of 3.2 plus or minus 0.86 could satisfactorily represent the ratio of "battery limits" costs* to equipment costs for a wide range of process plants. For the most part, such rules of thumb are based on extensive industrial plant construction experience but not on experience with environmental control systems. Retrofitting end-of-pipe treatment methods is likely to be more disruptive and constrained by existing facilities and thus more expensive than new construction. On the other hand, site preparation and costs for providing utility connections are likely to be lower for add-ons. No information has been found on how these rules of thumb might differ from the norm for environmental control projects.

---

* "Battery limits" is a geographic boundary defining the coverage of a specific plant, including all process equipment but excluding storage, utilities, administrative buildings, auxiliary facilities, and site preparation.

2.1.2 Operating Cost Estimates

Operating costs include labor, raw materials, energy, maintenance, and other recurring costs of operation of industrial facilities. In the engineering cost analysis approach, once the items of equipment and their sizes and operating characteristics have been specified, it is relatively straightforward to estimate the amounts of raw materials, energy and labor required to operate the facility in its early years. One must, of course, remain cognizant of the uncertainties in the future prices of such inputs over the lifetime of the project. Furthermore, operating inputs may decline substantially over time due to "learning," as discussed in Section 3.

Labor costs include both hourly and supervisory costs. Hourly labor requirements are generally specified based on the vendors' estimates of labor requirements, and supervisory labor is based on the application of a rule-of-thumb ratio such as 15% of supervision to direct labor. In this case also, it is not known whether environmental control devices require more or less supervision per unit of hourly labor than do production processes. There is some reason to think that the supervisory attention may be greater for environmental control systems, in view of the higher level in the firm at which environmental control decisions are generally made. (Ashford, Heaton and Priest, 1979)

2.1.3 Total Annualized Costs

The annualized cost of compliance consists of the sum of the annual operating costs and the annualized costs of owning capital plant and equipment. The translation of capital investment costs into annual costs of ownership is not straightforward or uniquely defined and is a major concern of the field of engineering economics discussed earlier. Generally, the annualized cost of owning capital plant and equipment must be recovered by the sum of the interest paid to debt holders, dividends paid to stock holders, and retained earnings. Since environmental control expenditures are not expected to produce a profit for a firm, it is unreasonable to expect equity investments to be made in them. Thus, it is common to assume that all capital expenditures for pollution control are financed by debt financing and to assign costs accordingly. (PEDCo, 1979, p. 53)

Both capital and operating costs are sensitive to scale economies in production and to the size of the firm in which they occur. In a regulatory analysis, one must analyze plants of a size typifying those existing in the industry in the case of retrofit requirements, or those expected to be built in the industry in the case of requirements for new plants. Scale factors for estimating the effects of facility size on costs are also published as rules of thumb, which are usually dimensionless exponents to be applied to capacity ratios. Typical values of such exponents are shown in Table 3 taken from Desai (1981). For example, if an agitator of one size is estimated to cost \$5,000, one that is three times as large would be expected to cost $(3)^{0.5}$ or 1.73 times as much, or about \$8,650.

Table 3

Recommended exponents for scaling equipment costs

Equipment	n values
Air Fins (coolers)	0.80
Agitator	0.50
Blower	0.65
Compressors, reciprocating and centrifugal	0.75
Conveyor	0.70
Drums	0.65
Dryer	0.50
Ejector (5-stage)	0.50
Heaters	0.80
Heat exchangers	0.60
Pumps	0.60
Refrigeration unit	0.75
Tanks	0.70
Towers	0.70

Source: Desai (1981)

2.2 Other Firm Level Costs

In addition to direct outlays for plant and equipment needed for compliance, regulation can impose other kinds of costs on the firm. These include the costs of lost production, of reduced productivity, of additional administration, of some plant closings, and of some kinds of changes in the firm's competitive strategy.

The treatment of lost production due to regulation is difficult. If a regulation does not cause price changes, then the value of lost production is simply equal to the amount of lost income minus the recurring expenditures of production. Some commentators argue that the value to the firm of lost production depends on the capacity utilization in the firm. (EPA, 1979) If the production that is lost during a period of regulatory changeover can be made up by increasing the operating rate of existing equipment before or after the changeover is made, then lost production may impose no costs whatsoever. Furthermore, it may be possible to install pollution control devices during normal maintenance periods, which would also create no costs or lost production. (PEDCo, 1979) Of course, some pollution control equipment permanently impairs plant capacity, and will impose costs if the plant could otherwise operate profitably at higher throughput.

If the engineering cost analysis is performed correctly, it should take into account the costs to the firm of changes in the productivities of labor, energy, and raw material inputs. However, if such lost productivity arises from the diversion of managerial resources from managing production to managing regulatory compliance, then there may be spillovers in which other nonregulated aspects of the firm also suffer a productivity loss. Currently, there is no known way to estimate such losses.

To meet regulatory requirements, firms must generally not only install equipment or change processes but also engage in a continuing series of activities related to monitoring, assessing, and reporting on the performance of compliance technologies. These costs must be considered real costs faced by the firm under regulation.

Within the static framework, plant closures have been a major item of analytic concern. Depending on the structure of the regulated industry and on the markets available to its firms, the imposition of new costs through regulation may serve to make one or more of the firms in the industry no longer profitable at prices the market will bear. From the static point of view, if a firm can no longer achieve an acceptable rate of return on its assets following regulation, that firm can be expected to close or to leave the line of business that is regulated. However, such an analysis assumes that firms have no slack resources and no ability to meet increased costs by using new technology. Thus, plant closure predictions based on static analyses are likely to be overly pessimistic. Furthermore, while plant closings may impose substantial costs on particular workers or communities, the cost to the regulated firm may be recoverable in part by shifting its assets to different purposes.

One of the more subtle impacts of regulation on the firm is that regulation can cause a firm to change its competitive strategy. This can be good or bad for the firm, depending on its original condition and on the new strategy that it adopts. For example, for many years the American auto industry had followed a competitive strategy of annual design change, standardized technology, and low price. New technologies and performance features were de-emphasized in American automobiles. Environmental and fuel economy regulations have caused the domestic automobile industry to shift its attention from styling and price to performance and new technology as elements of their competitive strategies. According to some commentators, this shift has been a positive one for the American industry, assisting it in coping with the challenge of Japanese and European imports. On the other hand, a regulation which causes a dynamic, rapidly changing firm to shift its strategy from growth and major change to consolidation and incremental change imposes long-run costs on the firm over and above those of compliance. This can happen, for example, if a regulation requires all the firms in a regulated industry to adopt a particular control device or process technology for compliance purposes.

3.0 The Dynamic Analysis of Firm-Level Costs: Technological Innovation and Change

The engineering economics and cost estimation approaches to analysis of the cost of industrial processes discussed in Section 2 are based on a snapshot view of the costs of technologies that are currently in use or whose cost parameters are anticipated by the state of the art of existing technology. When a private firm makes a decision to invest in a new process, it is entirely appropriate that such static analyses be used to define the costs for the firm's own cost/benefit decision model.* However, the problem faced by regulatory analysts and decisionmakers is different because (1) the technological responses of the firms in an industry to a regulation are expected to evolve over a significant period of time, (2) some firms in the industry, or that supply or depend on the industry, will develop substantially new and improved control and/or process technologies, and (3) a number of firms in the industry will be investing in the same or similar technologies at about the same time. These phenomena tend to cause the actual costs of purchasing and operating pollution control technologies or improved process technologies to be different from those that would be anticipated by a static engineering cost analysis.

This section examines the conceptual background and some empirical evidence for the impact of these dynamic phenomena on the cost of complying with regulation. First, it examines the importance of learning and experience in causing incremental reductions in the cost of operating technologies. Second, it examines how technological innovation, that is, the development, adoption and use of new technologies, influences regulatory compliance costs.

---

* In more sophisticated analyses of individual firm investment decisions, there is a growing interest in anticipating cost reductions due to learning and innovation over the lifetime of a proposed project.

Third, it examines how the shift in demand for equipment created by regulation tends to change the prices of control technologies and process inputs. Finally, it discusses the conflict that can arise for a firm in the long run between cost-reduction and performance-improvement strategies that focus on learning and on technological innovation, as well as the conflict between the cost-reducing and cost-increasing phenomena discussed earlier.

3.1 The Effects of Learning and Experience on Compliance Costs

3.1.1 The Nature of the Learning Curve

It is well known that the cost of performing any task in an organization tends to decline with repetition of the task. In many cases, a plot of the cost of performing a task versus the logarithm of the number of times the task is performed is a straight line. With every doubling of the number of performances of the task, its costs are reduced by a relatively constant fraction. First noticed in the 1920s in connection with the production of aircraft, the learning curve phenomenon has been generalized to encompass nearly all industrial activity. Typically, when the task to be performed involves a large labor content, the unit cost declines by 20 or 30% for every doubling of output. That is to say, the cost at the end of a doubling period is only 70 or 80% of the cost at the beginning of the period. When the task is based on a high proportion of machine input, the decline tends to be more gradual--in the neighborhood of 90% of the original cost at the end of every doubling period. (Hirschmann, 1964)

Learning occurs in organizations. It is the manifestation of the fact that employees in a firm from top management to hourly workers become more experienced and seek shortcuts to make their individual tasks easier and more effective. Such learning happens quite apart from any effort to make major improvements in technology and is distinct from the increases in productivity and quality or reductions in cost that occur when substantially different kinds of equipment are installed in a plant. In this sense, learning is indistinguishable from what is often called incremental innovation.

While learning is well established in assembly-type industries, it is less intuitively related to the continuous process technologies used in the industries with significant pollution problems and also used to control air and water effluents. Nevertheless, when examined carefully the evidence supports the existence of learning phenomena even within such facilities as petroleum refineries and petrochemical plants. (Hirschmann, 2964) Even with a well-established petrochemical plant or petroleum refinery, ways are found over time to increase the output of the facility with only small capital investments. This happens not only because the workers and managers of the plant learn how better to schedule and operate the facility, but also because engineers are not able to completely specify the performance of such facilities in advance. Generally, such facilities can produce at a higher rate than originally intended, subject to the removal of the bottlenecks that are found to constrict production in sequential processing operations. As the bottlenecks are eliminated by investments or by changes in operating parameters, production increases, but at a slower rate as output accumulates, again following a semi-logarithmic relationship. (Bodde, 1976)

An important finding from research on learning and experience curves is that, while learning appears to be automatic, it nevertheless requires repeated production of the same product, the continual attention of management, and the continual application of resources. Furthermore, while at any time the managers and engineers are not able to anticipate how costs will be reduced in the future, for learning to occur they must have faith that costs will go down. If everyone believes that a cost plateau has been achieved, then, indeed, costs are unlikely to decline.

Hirschmann has summarized the results of learning research in the form of what he calls "learning curve doctrine":

> 1. Where there is life, there can be learning.
>
> 2. The more complex the life, the greater the rate of learning. Man-paced operations are more susceptible to learning or can give greater rates of progress than machine-paced operations.
>
> 3. The rate of learning can be sufficiently regular to be predictive. Operations can develop trends which are characteristic of themselves. Projecting such established trends is more valid than assuming level performance or no learning.
>
> 4. Learning is related to the dynamic context of the environment. Faith and incentive stimulate progress, and provide the drive to exert the energy, resourcefulness, skill, and persistence needed to bring it about. Conversely, the "ceiling psychology" and the tendency to maintain the status quo, or not to rock the boat, inhibit learning. (Hirschmann, 1964, p. 138)

3.1.2 Learning and Regulatory Compliance

It is reasonable to expect that the learning curve phenomenon will apply to regulatory compliance costs in at least two ways. First, it is reasonable to expect that the costs of operating an existing pollution control facility will be reduced over time as operators and managers learn to make the facility perform better. If the pollution control facility is attached to a production plant whose output is increasing, then the burden of pollution control imposed on the control facility will also be increasing, and it will be scrutinized for possible improvements in performance and reductions in cost in the same way that the main part of the plant is examined. (Of course, the firm also has the option to allow the performance of the pollution control facility to degrade over time, risking an ever-increasing probability of violation of the standard. However, even if this happens, the cost of pollution control per unit of output will decline from the firm's perspective.)

Learning in pollution control may occur in another way. In many cases, pollution control equipment is bought from a specialized vendor. In this situation, learning occurs not only in the operating plant, but also in the vendor firm that makes the pollution control devices. For example, it seems reasonable to expect that, all other things remaining constant, the cost of building and installing the 100th cooling tower for electric power plants will be less than the cost of installing the first, the second, the fourth, or the eighth such tower. Since most pollution control devices are made by assembly industries, one could expect learning to proceed along a 70 or 80% learning curve rather than the more gradual 90% learning curve typical of process firms.

Learning phenomena in vendor firms, which may influence the prices charged for control equipment, depend on the underlying market structure. In ordinary rivalrous markets, if vendors anticipate learning, they may set initial prices lower than costs to establish a market position. If they enjoy a monopoly position vendors may retain the "excess" profits that accrue as costs decline due to learning by keeping prices constant. Any such noncompetitive behavior causes a divergence between the private (regulated firm) and social costs of regulation that should be considered by regulatory analysts. Unfortunately, no data base exists for assessing and forecasting vendor learning and associated price effects.

Since effective learning depends on a relatively stable market for the product, the demand for pollution control created by a regulatory regime should remain relatively stable if learning is to be effective. This does not necessarily mean that a standard must be fixed for the foreseeable future but that the rate of expected improvement is well established or that the mechanisms that trigger changes in the regulation are well known and understood. One of the weaknesses of command and control regulations that establish standards of performance is that such standards may tend to become ceilings on what is demanded from vendors and from operators, managers, and technical people in a firm. Once compliance is achieved, attention is turned to other matters and cost reduction and performance improvement through learning are inhibited. Of course, the costs of operating pollution control devices present a continual incentive for improvement. Economic incentive approaches to regulation can bolster this incentive, while avoiding establishment of a celing on performance. (See Section 6 for further discussion of the relationship of regulatory design to learning phenomena.)

3.2 Technological Innovation and Compliance Costs

3.2.1 The Nature and Sources of Technological Innovation

Technological innovation is the process of development, adoption, and use of technology that is new to the world, to the industry, or to the firm. Technological innovation includes new technologies that perform existing tasks more effectively or at lower costs, as well as technologies that allow us to accomplish entirely new tasks. Technological innovation occurs both in response to new opportunties created by advances in science and as the response of a firm that experiences the pressure of a need to change. Research and development (R&D) contributes to technological innovation by providing the bases for the generation of entirely new concepts for continual learning and improvement of existing products and processes. However, technological innovation can often occur in a firm in which there is no organized research and development function. (Hill, 1979b)

New technologies can have a variety of origins. While in the simplest case new technologies are developed by the firms that use them, many innovations originate in supplier firms or in firms that are users of the products of the industry in which the innovation occurs. For example, innovations in the aircraft industry may be supplied by the producers of engines or of electronic equipment, and new chemicals may be developed by the industrial customers of chemical-producing firms. As an industry grows and matures, the locus of major innovation shifts from new firms, to existing firms, to new entrants to the industry.

There is considerable evidence that small firms, new firms, and new entrants to an industry play major, if not dominant roles in innovation. (Utterback, 1979) This has been found to be true even in the case of the response of auto firms overseas to U.S. safety, emissions, and fuel economy regulations. (Ashford, Heaton, et al., 1981)

3.2.2 The Interactions of Technological Innovations and Regulations

Technological innovation affects both the costs and benefits of regulatory programs. At the same time, the design of a regulatory program can profoundly influence the innovative behavior of a regulated firm. (See Hill et al., 1975; Ashford, Heaton, and Priest, 1979; Grabowski and Vernon, 1979; a series of papers in Hill, 1979a; and Hill, 1979b, for reviews of the interactions of regulation and technological innovation.)

It is useful to consider a four-fold classification of the interactions of Government regulation and technological innovation. First, the rapid pace of technological innovation in the 20th century has blessed us with the technological systems whose hazardous side effects and great power are at the heart of the vastly incrased scope of Government regulation of the last two decades in all industrialized countries. Second, technological innovation can reduce the costs of regulatory compliance by providing new control technologies or new production processes that are more effective, less costly, or inherently cleaner than existing technologies. Third, regulation may divert financial and human resources from the ordinary course of technological innovation activities in industry or it may establish barriers to new ideas and, thus, inhibit innovation for ordinary business purposes. Fourth, at other times new Government regulations may stimulate technological innovation in industry and provide benefits to regulated firms even in areas other than those related to compliance.

This paper is concerned primarily with the second point above (innovation to reduce compliance costs) and to a lesser extent with the third and fourth (regulation can inhibit or stimulate innovation). It also examines how regulation can be designed so as to encourage the development and use of better control or process technologies for compliance purposes.

A careful examination of the first point (innovation creates the need for regulation) lies beyond the scope of this paper. Suffice it to say, however, that regulation has emerged, not as part of a general trend toward misguided interference in private affairs by big Government, but as an effective social mechanism for exerting control over the threats to these affairs by powerful technologies. Similarly, it is beyond the scope of this paper to review the theory and evidence on how regulation inhibits innovation for ordinary business purposes (a perspective well-represented by Grabowski and Vernon, 1979) or of how regulation stimulates innovation for main business purposes (see Hill, 1980, for an elaboration of this perspective and Royston, 1980, for an extensive set of examples).

3.2.3 Technological Innovation and Compliance Costs: Some Examples

Let us examine a hypothetical example of how technological innovation can affect regulatory compliance costs. Consider the case of air pollution control from a textile dyeing and finishing plant. If the basic dyeing process is not changed in response to pollution control demands, it is likely that the plant will have to install ventilating systems as well as devices for recovering or destroying chemical vapors in the exhaust air. It is unlikely that the textile firm would develop such systems and devices itself; rather, it would approach the existing vendors of ventilation systems to purchase control technologies. The ventilating system vendors in turn would probably try to adapt their existing lines of equipment to meet the needs of textile companies. They might engage in R&D to develop more effective or cheaper control technologies, but major advances might well come from firms that had not been involved in the ventilating equipment field at all. Alternatively, firms that sell textile finishing or dyeing chemicals to the textile industry might do research on methods of vapor recovery in the textile industry in order to protect the markets for their existing chemical lines. Or, they might do research on water-based textile chemicals that do not generate harmful vapors. Similarly, fiber makers might search for new fiber compositions or yarn types that could use entirely different methods of dyeing or finishing.

The regulatory analyst who seeks estimates of the cost of compliance with an emission standard for organic vapors from textile mills from the vendors of ventilating equipment is not likely to be aware of the R&D efforts of suppliers and consumers of fibers, textiles, textile chemicals, and textile machinery to develop better fibers, ventilating technologies, dyeing methods, or recovery systems, that will allow for lower cost technologies. Only if given extraordinary time, resources, and access to industry information will the regulatory analyst be able to acquire this knowledge. Even then, the more important the advance, the less likely is the analyst, or anyone else, to be able to anticipate it in advance. The result is likely to be a systematic overestimate of the ultimate cost of compliance. We currently have no basis for adjusting these overestimates.

Two actual examples might serve to illustrate dramatically the impact of technological innovation on regulatory compliance cost. The first example, taken from Dewees (1978), illustrates how the cost of control of automobile pollution has shifted as control technologies have been improved. Figure 1 illustrates these cost improvements over time. Each curve on Figure 1 represents the marginal costs of achieving each level of control using technologies available in each year. ("Net Percent Controlled" refers to a weighted average percent reduction of emissions of the three pollutants, CO, HC and NOx, compared with emissions from uncontrolled vehicles.) Obviously, in

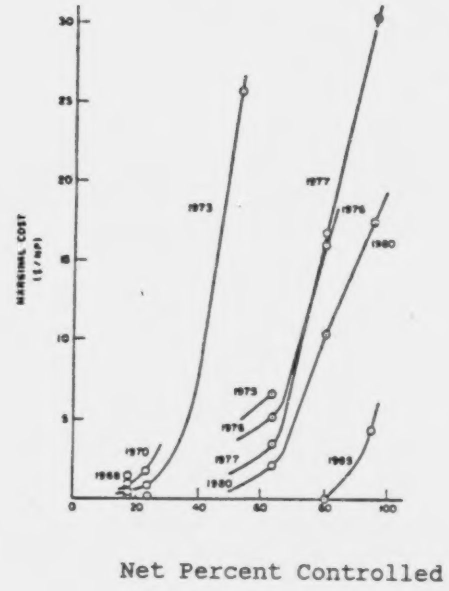


Figure 1. Marginal costs of standards at different dates.

Source: Dewees (1978)

any year, more control has cost more. But, equally obviously, over the 15-year period the costs of achieving a particular level of control have declined dramatically. The declines in the 1968-75 period arose from minor modifications of existing engine designs and from adoption of the catalytic converter--an end-of-pipe control technology. After 1975, the declines arose from major changes in engine technology including lean-burn and stratified charge engines. (It should be noted that parts of Figure 1 are Dewees' estimates of potential control costs and do not necessarily reflect actual technologies adopted by the manufacturers. No attempt has been made by this author to reconcile Dewees' paper with the paper by Joseph A. Vasquez in this volume.)

Dewees (1978) points out that currently we are not able to forecast the rate at which such curves appear or shift. This conclusion is consistent with the broader view that major technological advances are inherently unpredictable. (Klein, 1977, 1979) But, the situation is not necessarily hopeless for the regulatory analyst. For incremental improvements, the theory of induced innovation may provide a useful framework. For example, in one empirical modeling study, it was found that technology for producing synthetic ammonia from natural gas evolved in a quite regular fashion in response to changes in the prices of input factors over a 25-year period. (Greenberg, Hill and Newburger, 1979) Furthermore, the theory of induced innovation has been shown to apply in a number of other situations, especially in agricultural technology. (Binswanger and Ruttan, 1978) However, aside from some rather pro-forma modeling exercises by McCain (1978) and Magat (1978), no general guidelines have been developed that would facilitate prediction of the quantitative response of the costs or performance of new technologies to regulatory stimuli.

The second example is the control of worker exposure to vinyl chloride in polyvinyl chloride (PVC) manufacturing. Initial estimates of the cost of regulation were extraordinarily large, on the order of 65 to 90 billion dollars of lost sales and production. (A.D. Little, 1974) However, once the industry had turned its attention to the problem of worker exposure, not only were control cost orders of magnitude lower than estimated, but some firms were able to produce PVC at a lower cost than before the regulatory stimulus. (Ashford et al., 1980) This happened in part because the work exposure standard accelerated the adoption of new technology which was both more productive and safer. This result is consistent with Dewees' notion that regulation can accelerate the adoption of "dusty technology" already on the shelf. (Dewees, 1978) In another empirical study of chemical industry response to regulation, Ashford, Heaton, and Priest (1979) report that the majority of compliance responses used technology that was nearly commercial before regulation. (This finding, however, does not mean that an analyst could have found out about these "dusty technologies" for ex ante regulatory analysis purposes.)

3.2.4 Technology-Forcing Regulation

In several cases in the last decade Congress has adopted environmental legislation mandating the use of technologies that are more effective than those commercially available or in use at the time the legislation was passed.

Such regulation is commonly known as "technology-forcing" regulation. It can be viewed as being intended to cause the generation of entirely new technology or to accelerate the movement of "dusty technology" from the shelf to applications. However, Congress has rarely, if ever, mandated the use of technologies whose performance is entirely out of sight at the time the legislation is adopted. Rather, it has usually acted on the knowledge that technologies with performance in the desired range are at least at the developmental stage, and the purpose of the legislation is to accelerate their development and adoption.

Nevertheless, sometimes the technology ultimately adopted by the regulated firms is different from that anticipated at the time the technology-forcing regulations were adopted. The Clean Air Act mobile source control provisions provide an example of this phenomenon. When the Act was adopted in 1970, Congress could not have reasonably anticipated the oxygen-sensor, microprocessor controlled fuel delivery, three-way catalyst system that has been adopted by many auto firms since 1976. Yet that technology was ultimately adopted, rather than the electric car, the Sterling engine, or the gas turbine, which were under discussion in 1970. This discussion illustrates again the unpredictability of significant technological advance.

3.3 The Effect of Regulatory Demand on the Cost of Process Inputs and Techniques

Suppose that a cost engineer wishes to project the cost of a tertiary treatment system for water effluents from an electroplating plant. Following the usual procedures of engineering cost analysis, the analyst would describe at an appropriate level of detail the items of plant and equipment needed to perform the task for a model plant with specified performance parameters and size characteristics. Such a treatment facility might involve the construction of buildings, the erection of concrete settling tanks, and the purchase of equipment such as pumps, filters, and the like. The analyst would use ordinary procedures and handbooks to estimate the costs of structures and buildings and would contact equipment vendors for estimates of the prices of the various items of mechanical equipment and electrical control systems. Because the analyst would be proposing to purchase only a small number of items, vendors would be likely to quote current prices. In view of the procedures used by cost engineers, these equipment price quotes are the foundation upon which all other costs are developed.

Now suppose, however, that all of the firms in the industry will be installing similar equipment at about the same time in response to a new regulation under the Federal Water Pollution Control Act. The effect of the regulation is to cause a step increase in demand for the items of equipment necessary for the control facility. In economic terms, the demand curve has been shifted upward. As a result, the prices that firms will have to pay for equipment will be higher than quotes for a single purchase.

The importance of such demand-induced price changes for regulatory compliance costs has been examined in a series of studies performed by Thompson and colleagues at the University of Houston. For example, in work summarized in Thompson (1979) it was found that water treatment costs might be increased several-fold if uniform technology standards were applied to all industries nation-wide. It should be noted that a substantial and expensive modeling effort may be needed to estimate such cost increases credibly.

The phenomenon of demand-induced increases in regulatory compliance costs should not be confused with the phenomenon of systematic underestimation of project capital costs that has been observed in a wide range of major process plant projects. (Merrow, Phillips and Myers, 1981) While military cost overruns have been highly visible, undercosting is not limited to that sphere. For major new process plants and energy conversion technologies such as coal gasification and oil shale recovery, the capital cost estimates tend to escalate at a rate several times higher than the nominal rate of inflation. For major new technologies whose performance is unknown or uncertain, cost engineers systematically underestimate the difficulty of bringing those technologies on-line and, thus, systematically underestimate their costs. Merrow and colleagues found that the greatest source of error is use of inappropriate cost estimating methodologies, and that such factors as scope changes, inflation, environmental regulations, management practices, strikes, and bad weather are much less significant as contributors to underestimates of capital costs. The proponents of new technologies fail to grasp the cost implications of including multiple untried technologies in major first-of-a-kind projects.*

3.4 The Incompatibility of Learning and Technological Innovation Strategies

Recent research has shown that firms which adopt a strategy based on incremental improvements and learning curve phenomena may find themselves unable to make the major changes necessary to adapt to substantial changes in scientific understanding, market demand, and social requirements over the long run. Similarly, firms that emphasize major technological advances are not able to follow a strategy of incremental improvement in costs and productivity over time. Klein (1979) has called the ability to adapt to major changes in the environment "macro-stability" and the ability to make continued small changes "micro-stability." He asserts that there is a direct tradeoff for any firm between micro- and macro-stability.

The classic study in this area is by Abernathy and colleagues, who studied the dilemma faced by the Ford Motor Company in the 1920s as the Model T Ford reached the end of its commercial life. (Abernathy and Wayne, 1974, and Abernathy, 1978) Ford adopted the strategy of making continual incremental changes in the Model T, while the basic concept remained fixed. As a result of the incremental improvement strategy, the price in constant dollars of the Model T declined by a factor of nearly four over its 15-year life. However, when Ford was faced with major competition from General Motors in the early 1920s, the very efficient but inflexible structure it had established for making Model T's was almost unable to make the major change necessary to adapt to the new market conditions imposed by GM's annual model change strategy. Thus, Ford faced a major innovation crisis in the early 1920s as a result of its earlier successful strategy of incremental productivity improvement.

---

*Section 3.5 addresses the apparent conflict between the cost-reducing contributions of learning and innovation and the cost-increasing effects of innovation in first-of-a-kind facilities.

A similar crisis was experienced by the Volkswagen Corporation in the early 1970s as the "Beetle" reached the end of its 25-year commercial life. Volkswagen was almost unable to adapt to the changed demands of styling, performance, safety, and fuel economy imposed on it by its competitors and by Government regulations in the early 1970s.

Firms generally follow one of a small number of strategies with respect to technological change. Some firms try to maintain a continual flow of new technologies having significantly improved performance or reduced cost. Others depend on long production runs of relatively standard items that allow them to take advantage of both economies of scale and incremental learning over time. Neither strategy is necessarily better, but, as noted above, firms can not excel at both simultaneously--a balance is required.

The technology strategies of firms that make or operate pollution control equipment or less-polluting processes have not yet become generally apparent. There is some evidence that the technological responses of firms to regulatory requirements may not be conditioned by their pre-existing technology strategies. In a study of the response of the chemical industry to environmental requirements, Ashford and Heaton (1979) found that both "fluid" and "rigid" firms tended to make changes in technologies that could be considered equally novel. (In this study a fluid firm is one that is engaged in rapid technological change while a rigid firm uses a more established and less rapidly changing technology.) Both rigid and fluid firms were likely to use technologies whose parameters were already known. These results suggest that the design of regulation need not take into account the state of the technology in the regulated industry to achieve an effective response to regulatory requirements.

It is not clear whether these findings for the chemical industry can be extrapolated to industry generally, however. For example, in a mature industry with relatively slowly changing technology and relatively small numbers of new entrants, it is unlikely that the firms in the industry would develop pollution control methods with lower costs than those they might be able to purchase off the shelf. In this case, regulation might be more effective and cause lower costs if it were designed to encourage firms from outside the industry to develop pollution control equipment and cleaner process technologies. This might be done, for example, by Government support of pollution control R&D in firms not traditionally associated with the regulated industry, or in laboratories and universities that encourage the spin-off of new firms.

Furthermore, in these rigid industries, design-based standards may be most effective. On the other hand, industries whose technology base is more fluid may respond more effectively to performance standards that encourage major change. More research on industrial responses is needed to determine under what circumstances it would be important for the technological demands of regulation to be coherent with the dominant technology strategy of firms in the regulated industry.

3.5 Resolving the Cost-Reducing and Cost-Increasing Effects of Innovation

This section has emphasized how technological innovation and learning can be expected to reduce the costs of regulatory compliance below those predicted by static engineering cost analysis. But, at the same time, mention has been made of the work of Merrow and colleagues (1981) on cost overruns, which shows that cost estimates for new, technological projects are often quite low. These arguments might appear to be contradictory, but there is a simple resolution of the apparent difference.

In the compliance innovation case, the baseline cost estimates are usually made for relatively well-known, state-of-the-art, end-of-pipe technologies. These approaches are usually known to work and have relatively well-defined costs and performance parameters. Within the limitations of "study" estimates for model plants noted in Section 2, their costs can be estimated with some confidence. Subsequently, compliance innovations are only successful if they can offer lower-cost solutions--while one firm might experience cost overruns trying a new approach to compliance, a new technique that is found to be more expensive than well-known approaches is unlikely to be widely adopted. Thus, innovation can not raise compliance costs in the aggregate significantly higher than end-of-pipe costs.

In the cost overrun cases examined by Merrow, the excess overruns arise from the presence of key elements of untried technology in the baseline first-of-a-kind plant. Either there is no prior, well-understood baseline case (as, for example, in advanced weaponry) or the cost constraint of the well-known baseline case is artifically suppressed (as, for example, in the synthetic fuels case). Thus, only in cases where there is no well-understood control technology at the time the regulatory analysis is performed, could innovation be expected to cause costs of compliance to exceed those projected ex ante.

4.0 The Analysis of Industry-Level Costs

The two previous sections have discussed the analysis of the costs of compliance with regulation in individual firms. These must be aggregated across an industry or across geographic regions in order to estimate the aggregate cost of a regulatory requirement for an industry or the Nation. This section discusses two major considerations in aggregation. First, it examines the question of access to compliance cost estimates and how such data should be acquired. Then it discusses several issues that arise in aggregating cost estimates across firms.

4.1 Sources of Compliance Cost Data

There are two basic ways to acquire data for compliance costs estimates. The first is to survey firms in the regulated industry for their estimates of what a proposed regulation will cost at each of their facilities. The second is to do a detailed engineering cost analysis for model plants, modified as appropriate to account for innovation and learning. The model plant approach is generally used.

There are at least three problems with the industry survey approach. First, unless both the Government agency (or its contractor) and the responding firms pay a great deal of attention to defining the scope of the compliance technology, it is unlikely that cost information will be presented on a sufficiently consistent basis to allow for comparisons across firms or against independent estimates. Second, there is an obvious incentive for firms threatened with regulation to overestimate their costs of compliance. Third, agencies have limited or no authority to compel firms to respond to a cost survey, so the sampling bias in the responses is likely to favor an overestimate of total costs.

There are also difficulties with the engineering cost analysis approach to compliance costs. First, for many pollution control technologies there are no standard sources of information because there is little or no experience upon which to assess their costs. Thus, the analyst must make a greater number of assumptions and must operate in a more uncertain cost environment than the engineering cost analyst who is examining a standard production technology. Second, the more creative responses to environmental control requirements involve modifications in existing processes or the adoption of entirely new processes that produce fewer environmental effluents. For the most part, a regulatory analyst in an agency or its contractor is in a weak position to anticipate these more creative responses. Third, the analyst is also in a weak position to forecast the impacts of learning or incremental technological innovation on any particular compliance technology. Finally, the most effective and lowest cost approach to controlling a particular hazard may be developed and marketed by a firm which has not been part of the regulated industry or one of its supplier firms in the past. In this case, it is almost impossible for an industry respondent or a regulatory analyst to be aware of the potential of a new technology that might operate at lower cost.

As a result of the above considerations, the regulatory analyst and the regulatory decisionmaker face an important dilemma in trying to do cost analysis and in trying to base regulatory decisions on a cost/benefit criterion. The analyst and the decisionmaker are likely to be most certain about the costs of the least-creative and highest-cost environmental controls, and are likely to be least certain about the costs of the most-creative and lowest-cost approaches. Thus, in using cost/benefit analysis there is a systematic bias toward overestimating the cost of compliance with any particular regulatory requirement. Until considerable additional research is done to compare ex ante and ex post estimates of the costs of regulatory compliance, it is unlikely that there will be any basis for estimating the impacts of learning and of innovation on compliance costs in a rational way.

One initial attempt to make such comparisons was performed by Putnam, Hayes, and Bartlett (PHB, 1980) on behalf of EPA. In that study it was found that both EPA and the regulated industries make substantial errors in estimating capital costs for pollution control as compared with actual costs from survey data. The errors by EPA ranged from 26% low to 156% high, and the industry errors ranged from 25% low to 162% high. Though the error ranges are the same, the EPA estimates tend to be more accurate than those of the regulated industries. PHB did not attempt a detailed analysis of the factors and assumptions that led to the overestimates of costs ex ante. Furthermore, this study was performed at an industry-wide level and provides no guidelines or rules of thumb for correcting a static cost estimate to account for innovation and learning for a particular technology or a particular pollution control regime. While systematic prediction of technological advance is not possible (and may never be), it would appear to be important that more work be done to understand the relationship between compliance costs and the nature of the regulation, the regulated industry, and its technology.

4.2 Aggregating Costs Across Firms

Once cost estimates have been made for model plants at some level of accuracy, the regulatory cost analyst must aggregate them across all the firms now in, or likely to enter, the industry. This subsection addresses several issues that must be considered in aggregating such costs.

4.2.1 Projecting Compliance Levels

In the case of command and control regulations for air and water pollution and solid waste, it is inadequate to assume for purposes of either effectiveness (benefits) analysis or cost analysis that all the firms in the industry are or will be in compliance with the regulation at a particular time. Since most environmental control regimes involve State and local enforcement, the pattern of compliance depends on the vigor of enforcement within the various State and local jurisdictions. Furthermore, States and localities are likely to give variances to noncomplying firms as a way to take into account the financial conditions of the firms or other extenuating circumstances.

Firms will adopt a variety of postures with respect to the risk of detection of violations and the severity of the consequences of detection. Since the performance of any item of process equipment, including pollution control devices, is characterized by a probability distribution, there is always some probability, however small, that a firm will be found not to be in compliance at a particular time. Since greater equipment reliability and a consequent higher probability of being found in compliance generally costs more, a firm obviously faces a tradeoff between the costs of compliance and the costs of a violation.

Clearly, the extent of compliance resulting from enforcement behavior and firm strategies will influence the aggregate costs of compliance with a new regulation. Unfortunately, there are very few data on compliance levels and no general models for forecasting them. This is an area where there is a great need for more study.

4.2.2 Model Plants and Industry Diversity

The population of model plants for which cost estimates are made must be a fair and accurate representation of the relevant population of actual plants in the industry. For a regulation that applies to existing plants, the relevant population is, of course, the set of existing plants, less any that are expected to close for reasons unrelated to regulation before the regulation takes effect. For a requirement that applies to new plants, the analyst must anticipate the sizes and locations of plants that are likely to be built during the period for which the regulation is in effect and to which the analysis applies. In the latter case, the analyst must talk with a diverse set of students of the industry to obtain a set of scenarios for the future development of the industry.

The total costs for an industry in the aggregate, as obtained from model plant calculations, must be modified to account for such local factors as the prices of inputs in local markets, and for additional costs due to bad weather, water shortages, the conditions of soils for solid waste disposal, and so on. An accurate estimate of the cost of a regulation for an industry must take into account these local circumstances, as well as the enforcement and compliance expectations.

4.2.3 Quantity Discounts

In estimating the costs of any pollution control device, one must take into account the number of such devices to be purchased by each firm. As noted above, the simultaneous purchase of a larger number (compared with the total market) of devices to comply with a new regulation may shift the demand curve upward and thus increase the price that has to be paid by each of the regulated firms. On the other hand, list prices of standard equipment such as pumps, piping, or measurement devices may be discounted to large purchasers. Thus, one must take into account the total number purchased, the scheduling of purchases, and the pricing policies of the suppliers to get an accurate cost estimate.

5.0 Other Considerations in Cost Analysis

A fair and accurate analysis of the cost imposed on an industry by any particular regulation must take into account several other considerations discussed in this section.

5.1 Selecting an Appropriate Baseline for Comparison

The cost of any regulatory requirement is the cost of achieving some new state of industrial performance as compared with some other state. Thus, it is important not only to estimate appropriately the cost of the regulated state but also the cost of the state of nonregulation or alternative regulation. Several issues regarding the choice of an appropriate baseline for comparison have been discussed in connection with the analysis of benefits of regulation by Hattis and Ashford (CPA, 1981--see also Ashford et al., 1980) and they apply to cost analysis as well.

First, if a proposed regulation is not promulgated, other forces will often cause the polluting industry to achieve some level of environmental control. These include voluntary action to improve the firm's image, to recover valuable components of the effluent, or because of a felt corporate responsibility; the impact of political pressure by affected communities; the threat of future regulation; private legal actions brought under the common law to control the effluent; and spillover effects from other regulatory regimes that cause the industry to achieve some level of control. If any of these corollary forces is in operation, it is not appropriate to assume that a condition of unrestrained emissions is the baseline against which to compare the regulated one. Instead, the analyst must examine these other forces and estimate the costs industry is likely to incur in response to them in the absence of the proposed regulation. Only these incremental costs should be counted.

Second, there is the problem of what to do about costs when compliance with a pre-existing regulation is not complete. Hattis and Ashford have discussed this circumstance in some detail in connection with the analysis of regulatory benefits. In parallel with their discussion, it would appear to be technically and politically correct to assume that the costs of compliance with an additional regulation are represented by the difference between the cost of compliance with the new standard and the cost of compliance with the old standard. Any costs that should have been incurred to go from the current state of noncompliance to compliance with the pre-existing regulation should not be attributed to the new regulatory requirement. Similarly, of course, the cost of the new regulation should be based on a realistic assessment of the degree of compliance with it. (See Section 4.2.1)

5.2 Spillovers to Other Regulations

The existence of other supplementary or complementary regulations on an industry can affect the cost of compliance in at least two ways. For example, an air pollution standard may require changes in an industrial process that can conflict with or support other changes required to meet water pollution, solid waste, or occupational standards.

When complying with one regulation also causes a firm to comply with some other existing or proposed regulation, the costs of compliance should be allocated between the two regulatory regimes. This avoids double counting of costs and reflects a more accurate cost for the regulation under consideration.

In some circumstances the requirements of two or more coexisting regulations are incoherent and create costs of overlap. That is to say, regulation A might cost \$1 million alone and regulation B might cost \$2 million alone but the combination of A and B might cost \$4 million. (See for example, Lave, 1981.) In such a case, the regulator may wish to examine alternatives to the regulatory designs that avoid creating an extra cost of incoherence. If such extra costs are unavoidable (such as when recovery of an air pollutant creates a new source of polluted water), it is necessary to allocate part of the extra costs of compliance to each of the two requirements. However, one should also take care not to base estimates of the costs of incoherence on the cost tradeoffs implied by the performance of existing technologies--a conceptual limitation of the Lave paper. Instead, the threat of incoherence requirements may be a stimulus for firms to seek new technologies that avoid the costs of tradeoffs along existing performance functions.

5.3 The Treatment of Joint Costs for Compliance and Protection

Frequently, changing a process technology for the purpose of regulatory compliance provides an opportunity for the firm to improve the productivity, performance, or cost of the regulated technology for ordinary business purposes. The new investment that was stimulated by the regulation may actually create an overall cost savings for the firm. (See Hill, 1980, and Royston, 1980.) In such cases, the cost of regulation should be only any marginal costs created by the regulatory requirement and not the full cost of the new production equipment or even the full cost of compliance to the extent that it has been offset by benefits gained by improved productivity.

5.4 Social Versus Private Costs

This paper is almost entirely concerned with the private costs to firms of complying with regulations. It is beyond its scope to delve into the relationship of these private costs to the true social costs of regulatory compliance. To be meaningful, cost/benefit analysis must be based on true social costs and benefits, not on private costs and benefits alone.* For example, such matters as subsidies for regulatory equipment and special tax treatment of compliance investments under the Internal Revenue Code do not change the true social costs of compliance, even though they may reduce the apparent private costs to the firm.

The regulatory cost increases faced by a firm are not paid by that firm, when they can be passed backward to suppliers or forward to consumers. Thus, the total social costs can exceed the costs paid by the regulated firm. The ability to make such cost transfers depends on the elasticities of supply and demand and the competitive conditions of the market within which the regulated firm sells. Analyses of these cost transfers are, of course, at the heart of modern welfare economic analysis. What is striking in examining the literature on welfare analysis applied to pollution control is that welfare analysts frequently apply sophisticated welfare considerations to naive estimates of private costs given by engineering cost analysis. (Similarly, of course, the engineering cost analysis rarely pays attention to welfare considerations, not even to externalities.) We have encountered no instance of regulatory analysis in which both the engineering cost analysis and the welfare analysis reflect the best of both fields.

---

*An example of not considering adequately the difference between private costs and social costs is the idea for a national "regulatory budget" that would set a cap on the annual imposition of private costs by regulation. (DeMuth, 1980) From a utilitarian (social cost/benefit) perspective, the regulatory budget makes no sense. The issue is not private costs alone, but the net of social benefits over social costs.

6.0 The Effects of Regulatory Design on Compliance Costs

The first objective of any environmental regulation is to reduce risks and control hazards to human health and to the natural environment. However, a responsible regulator would also like to control such risks at the lowest cost to society. Within the limitations noted in Section 5.4 regarding social vs. private costs, this generally translates to the goal of controlling risks at the lowest cost to the regulated industry. This section considers how the design of a regulatory regime can affect the costs of compliance. It considers both command and control regulations that set standards for design or performance of technologies, and economic incentive regulations that are intended to influence the behavior of polluters by increasing the costs of polluting.

Minimizing the cost of a regulatory requirement can be considered in both static and dynamic frameworks. From a static perspective, one chooses a regulatory approach that creates the lowest possible cost while achieving the desired level of control. From a dynamic perspective, however, one hopes to create incentives for both continual cost reduction and continual improvement in the degree of control over time.* One example of an existing regulatory regime that achieves a degree of dynamic performance is the prevention of significant deterioration (PSD) provisions of the Clean Air Act. Effectively, as the available increment is consumed the PSD provisions set ever tighter standards of performance for polluters in each attainment region. Likewise, the emission offsets provisions now being implemented by EPA, to provide the opportunity for continued industrial development in nonattainment regions, require each new polluter to achieve a better level of emissions performance than the pre-existing plants from which offsets are obtained. Both of these approaches have the virtue of providing an incentive for steady improvement and thus encourage innovative approaches to environmental controls.

6.1 Command and Control Regulations

Both the institutional arrangements and the structural details of a command and control regulation affect the costs to regulated firms and their propensities to innovate.

6.1.1 Institutional Aspects of Command and Control Regulations

Congress occasionally sets regulatory standards itself, as in the passenger vehicle emission standards under the mobile source provisions of the Clean Air Act. However, the vast majority of standards setting is delegated to administrative agencies, as in the stationary source provisions of the Clean

---

*Clearly, as the overall productive activity in the economy and the associated potential to pollute grow, achieving and maintaining a desired level of public health protection require continual improvement in environmental control technologies. Thus, the Nation's environmental objectives must be dynamic in the long run.

Air Act, the effluent standards under FWPCA, and the hazardous waste management standards under RCRA. It is generally believed that Congressionally-established standards provide a regulated industry with greater certainty about the emission levels to be achieved, but that they do so at the expense of a less careful consideration of the detailed tradeoffs between control levels and costs in particular industries or locations. However, experience with the frequent changes in the mobile source standards suggests that, if anything, Congressionally-mandated standards may be more erratic and uncertain than agency-promulgated standards. If this is generally true, then Congressionally-mandated standards can be expected to create high static costs and not take advantage of the dynamic effects of learning, since the control target will change frequently. More research is needed on the relative cost and innovation impacts of Congressional and agency standards.

The roles of the various levels of government in a regulatory regime also affect its costs. If nationwide standards are set at the Federal level and enforced by Federal agents, there is less chance that compliance requirements can be tailored to meet local conditions, and static costs will be higher than if standards are set and enforced locally. On the other hand, national standards help aggregate the market for pollution control equipment and make it more likely that learning and innovation will reduce overall costs of compliance over time. We are unaware of empirical studies of the tradeoff between these two effects on costs.

Government support of research and development for compliance purposes may help to reduce the costs of compliance by making cheaper technologies available to the regulated industry. On the other hand, from a dynamic point of view, heavy support of R&D by Government may undercut the private innovative efforts that might otherwise take place and thus weaken the incentive for private firms to develop better technologies. Furthermore, some of the incentives present in publicly-funded R&D programs emphasize incremental improvements in existing technologies and discourage the risk-taking needed to make major technological advances. These incentives include the paradigm-bound peer review system, the fact that funding agency managers are not rewarded for major advance but are penalized for failure, and the proper demand for high accountability in spending the public's funds. Thus, while R&D support might appear to be desirable at first, it may be better for Government to enforce standards vigorously and to reduce its involvement in R&D funding to the level necessary to maintain agency staff capability, identify new problems, and develop controls only for fragmented or marginal markets of high social value.

Government can help ensure markets for major new pollution control technologies if it structures regulations to require the use of best available technologies, rather than to achieve a particular standard of performance at a point in time. However, in requiring best available technology, it is important not to create disincentives for industry to develop new technologies. For example, if firms know that any better technology will have to be used in all of their facilities, they may avoid developing and promoting better control technologies. Thus, "best available technology" can not be taken literally by regulatory agencies. Similarly, a Government mandate to license control of technology patents to competitors, in order to facilitate the diffusion of new control technologies, may weaken the financial incentives that encourage firms to develop improved control technologies.

6.1.2 Structural Details of Command and Control Regulations

The type of standard influences costs, cost analysis, and innovation. Design standards, which specify the methods to be used to reduce pollution, provide the most easily assessed costs since the analyst can describe the technology that is to be costed.* Enforcement costs are substantially lower than for performance standards, because once an inspector learns about the design, inspections consume less time than is needed to measure performance.** However, in principle compliance costs are expected to be high for design standards.

Performance standards, which specify only the allowable emission levels, allow use of various technologies to reach the goal of the regulation and, in principle, allow for achieving lower compliance costs than design standards, in both static and dynamic terms. Performance standards make the job of the regulatory analyst in calculating compliance costs more difficult, because the analyst must examine all possible approaches and forecast which firms will employ each of them. There is no practical way to undertake a comprehensive analysis of the cost of a performance standard unless the responses of all firms are assumed to be similar. If different control systems are used to meet performance standards, inspectors may have a difficult time determining compliance, and administrative costs will be high.

It is generally believed that performance standards are better than design standards for encouraging the development and adoption of better pollution control technologies.*** The argument is that a performance standard allows industry greater latitude for creative response to regulatory requirements. However, the structure of the regulated industry can modify this general conclusion. For example, some polluting industries are highly fragmented, consisting of many small firms whose production technologies differ only slightly. Such firms do not have the resources necessary to take advantage of the flexibility of performance standards. In fact, the testing and evaluation necessary to meet a performance standard may impose a higher cost burden on such firms than simply defining compliance for them as the adoption and use of technologies of specific design. Furthermore, if such industries can use a standard design, this may allow the firms who supply those designs to learn and to sell a large enough number of units to support an R&D effort to improve the performance or reduce the cost of those control technologies. On the other hand, performance standards can be more effective and impose much lower costs for industries that are in a stage of rapid growth and development and whose basic process technologies are evolving rapidly.*

---

* This is not to suggest that the ease of analysis should lead society to favor design over performance standards, but only that a regulatory decision procedure based on cost/benefit analysis will unduly favor design standards.

**Frequently, regulators have chosen design over performance standards on effectiveness grounds, arguing that enforcing performance standards in the field can be impossibly costly, time-consuming, or hazardous. Examples can be found in areas as diverse as building codes and hazardous cargo regulations in coastal shipping.

***The distinction between design and performance standards is not so clear in practice. Often, agencies describe at least one design that will be acceptable in meeting a performance standard. Also, actual standards are often a hybrid of design and performance types.

The detailed structure of a regulatory standard can influence the reliability, and therefore the redundancy and capacity of control systems required for compliance. Air and water quality standards are usually structured in terms of the maximum allowable number of exceptional episodes per year. For example, a particular level of emissions might be allowed to be exceeded only for 4-hour periods, three times a year. It may make a large difference to the compliance cost whether a given level can be exceeded for 4 hours or 6 hours, or whether it can be exceeded twice a year or five times a year. The influence of this design parameter on compliance cost depends on the probability distributions of the performance of the production technology, the control technology, and the monitoring and enforcement mechanisms. Against such cost considerations must be traded off both the public health implications of allowing variances from the standard, and the implications of such reliability distributions for the operational practices adopted by firms. Operational practices can be important if the firm takes advantage of an exception provision of a standard to periodically clean dirty items of equipment or to adopt a generally lower standard of care.

Finally, the timing and phasing of regulatory requirements may have a large effect on the propensity and ability of regulated firms to learn or to innovate in order to reduce compliance costs. If the time allowed for compliance is too short, the regulation will induce adoption of end-of-pipe approaches that result in no significant change in operating procedures, except that a system that may interfere with the production process may be attached to the end of an emission pipe. End-of-pipe approaches, which often appear to be the least expensive approach in the short run, can easily be assessed by cost analysts, but they often create unexpected problems for the process. The hidden costs of end-of-pipe approaches are that they often fail to achieve the objective, require substantial maintenance, and are viewed as "that mismatched stuff at the end of the pipe that screws everything up."

On the other hand, longer compliance delays that allow adequate time for major changes in processes and control technologies do not disrupt normal behavior, but also may not impress the firm as serious. If it is not perceived as serious, as the deadline for compliance approaches the effective time for compliance becomes short and add-ons again dominate. While longer delays provide the opportunity for technological innovation, small innovators and new entrants can not undertake a technically risky project if potential rewards are years away. Of course, longer compliance delays also mean that the hazard persists and continues to threaten injury and impose costs.

---

*Such innovative industries can pose special problems for responsible regulation, if unnecessary inhibition of desirable innovation is to be avoided. See, for example, Hill, Andrews, Frenkel, et al. (1980) and the synfuels regulation strategies discussed by the EPA/DOE Interagency Energy/Environment Task Force.

Phasing of a standard, which is intended to achieve some control while major improvement is worked on, can induce the same sort of behavior as a short compliance time. Furthermore, each step of a phased-in regulation requires a marginal reduction in emissions, which is met by marginal technical change. Again costs are lower in the short term. But if they fail to align technically with evolving market trends, marginal changes can be expensive approaches for the firm and society.

The response of the automobile industry to the Clean Air Act requirements provides a good example of this problem. (Kagan, 1979) At each step of the phased-in Clean Air Act requirements the auto companies made another marginal change. The concept of major technical change to meet evolving market needs for low emissions and high fuel economy was not widely accepted until the late 1970s. The U.S. automobile industry is now paying the cost of its earlier narrow view of compliance by having to engage in crash programs to meet regulations and market demands.

In a recent study of the response of the foreign automobile industry to U.S. regulatory requirements, we found that the Swedish automobile companies, SAAB and Volvo, made especially creative responses to U.S. air pollution control requirements early in the cycle of phased standards under the Clean Air Act because they felt unable to cope with a frequently changing standard in a marginal way. (Hill and Andrews, 1980) Early in the game they developed and adopted a technology that would be able to achieve the ultimate levels of control expected under the Clear Air Act, a technology using a 3-way catalyst, oxygen sensor, and microprocessor feedback control of fuel and air supply using fuel injection. They were unable to take advantage of the phased-in application of standards under the Act and took the chance on making a major advance instead. From their perspective, it was fortunate that they succeeded.

More generally, regulatory requirements that are tightened in successive steps over time may work against learning and technological innovation by the regulated industry and its suppliers. The regulated firms may find themselves so busy coping with the immediate requirements of marginally improved performance that they can never turn their attention to making the kinds of major changes that would allow them to meet future requirements at lower costs. On the other hand, firms may choose to delay compliance with major changes in the hope that the regulation will be rolled back or that another firm will develop a cheaper compliance technology in the interim. There is a need for further research to understand the relationship between timing and phasing of regulations and industry response. Such research should consider the industry response not from a static economic perspective, but from the perspective of the strategic games that are played by firms and by regulators.

6.2 Economic Incentive Regulation

The last several years have witnessed a growing interest in the substitution of economic incentives for command and control regulations in circumstances where such incentives as pollution taxes or fees can effectively influence firm behavior to meet social goals. Economic incentives for pollution control might also be created by establishing a market in the right to pollute, as with transferable discharge permits.

The static rationale for these approaches, derived from the theory of externalities, suggests that a tax or effluent fee might be used to internalize the costs of environmental degradation, thus causing firms to reduce those costs by controlling their effluents. The dynamic rationale for the economic incentives approaches is that they provide a continuing incentive for technological improvement. From this perspective, it is not so much a matter of getting the externalities straight as it is of using economic incentives to encourage more rapid and continuing improvement in environmental performance. To date, little research has been done to design optimal strategies for using economic incentives to encourage continuing improvements in pollution control. (Nelson, 1978, and Klein, 1981) Nearly all the existing discussion considers the pros and cons of economic incentives in a static, externalities framework. (Oates and Baumol, 1975; Anderson et al., 1977; Kneese and Schultze, 1975)

From the perspective of the regulatory cost analyst, economic incentive programs would be more difficult to assess than command and control programs. For the latter, the cost analyst can specify with some certainty what the industrial repsonse is likely to be, assuming good faith compliance. The analyst does engineering cost analysis for existing technologies, perhaps modified by whatever he is able to judge about the dynamics of learning and innovation.

On the other hand, for economic incentives one must first estimate what the response of the regulated industry might be to, for example, an effluent fee, a marketable permit system, or a pollution tax. This requires not only an estimate of the cost of achieving a particular level of control, but also an estimate of the costs of a range of levels of control as the basis for generating a supply curve for environmental control. The analyst must then identify the technologies and performance levels for which the marginal costs of control are just equal to the marginal savings from avoiding the pollution fee for each real or model plant. Fortunately, the analyst can assume that an effluent fee or pollution tax sets an upper bound on the cost of regulation to industry, since no rational firm would control its effluents to a level that would cost more than paying the fee. However, other more complex economic incentive approaches such as marketable permits or auction systems provide serious conceptual and practical difficulties for the regulatory analyst, since he can no longer fall back on the size of the effluent fee or tax to establish the maximum cost of compliance. The analytic problems with these approaches, which derive from their virtue that they encourage a diverse response, may effectively preclude systematic decisionmaking based on formal cost/benefit analysis for such purposes as setting emission fees, determining the initial price of transferable discharge permits, or determining the optimal numbers of such permits to be issued. (The latter problem would remain, even if the permits were initially auctioned.)

These observations suggest that the choice between command and control and economic incentive regulations by the legislature may reflect the legislators' preferences for the allocation of uncertainty. For example, for an effluent fee approach one is very uncertain about the proper fee, the technological response, and the benefits of pollution control; but the fee sets a known limit on the regulation's cost and makes enforcement using the tax collection system relatively straightforward. By contrast, a performance standard offers less technological uncertainty and greater certainty of achieving a particular level of control, but offers great uncertainty about compliance costs and makes enforcement complex. Also, as noted by Kneese and Schultz (1975), there are circumstances in which equities and technical realities limit the application of the economic incentive approach. Mixed approaches may offer the best balance of achieving environmental goals and controlling regulatory costs. These include such tools as bubbles, offsets, and noncompliance penalties pegged to cost savings or benefits foregone. While these offer the potential for technological improvement, no empirical research has yet been done to evaluate the impact on innovation of the mixed approaches that are curently being tried.

7.0 Findings and Conclusion

7.1 Regulatory Cost Analysis

In view of the statutory and Presidential demands for basing regulatory decisions on analyses of their costs and benefits, it is imperative that their costs and benefits be assessed accurately and fairly.

Currently, the costs of proposed regulations are assessed using methods of cost engineering that have been developed for entirely different purposes. These methods are not appropriate for regulatory analysis. Their use causes a systematic overstatement of the ex ante costs of regulatory proposals.

Cost engineering has evolved as a method for guiding individual firms in making private investment decisions about technologies with performance parameters and design characteristics that are well known or that can be projected within reasonable limits. Cost engineering is inherently a static mode of analysis that does not account for change.

Environmental regulation, on the other hand, is intended to cause firms in an industry to change the technologies they use so as to control the risks they pose to human health and environmental quality. Assessing the costs of making such changes inherently requires a dynamic mode of analysis that can account for change.

The regulatory analyst and the regulatory decisionmaker are likely to be most certain about the costs of the least-creative and highest-cost environmental controls, and are likely to be least certain about the costs of the most-creative and lowest-cost approaches. Until considerable additional research is done to compare ex ante and ex post estimates of the costs of regulatory compliance, it is unlikely that there will be any basis for estimating the impacts of learning and of innovation on compliance costs in a rational way. To the extent that regulatory decisions are based on cost/benefit analysis, currently-used methods of cost analysis will lead to inadequate control of environmental hazards.

7.2 Research Needs

Despite a decade of theoretical analysis, case studies, and modeling efforts, there is surprisingly little systematic understanding of how technological change and the learning curve phenomenon influence the costs of firms' adaptation to a changed economic or regulatory environment. The regulatory analyst, faced with the practical problem of advising a regulatory decisionmaker about the economic consequences of a proposal, has nowhere to turn for guidance in doing proper analyses other than the fragmentary anecdotal literature of the type reviewed in this paper. If static engineering cost analyses are inadequate and inaccurate, can they be brought into line by applying a "correction factor" that varies in a systematic way with characteristics of the regulated industry, its markets, its technology, and the design of the regulation? Or, is some entirely different mode of forecasting more likely to be useful?

Since regulatory analysis is now firmly established as a policy, if not in concept or detail, there is an urgent need to learn how better to analyze and project regulation's consequences, both its costs and its benefits. Interestingly, both the costs and the benefits depend critically on the nature of the industrial response to regulatory requirements, both in terms of compliance behavior and in terms of the technologies that are developed and adopted to achieve compliance.

This paper has identified a number of research areas that are worthy of further study, not only for the immediate purpose of improving regulatory cost analysis, but also to improve the design of regulation and to enhance our understanding of the technological response of industry to all types of changes in its environment, including regulation. The following topics stand out as research needs:

1. Extend existing models of the impact of regulation on technological innovation, based on behavioral theories of dynamic response.

2. Document and analyze the responses of a variety of industries and firms to regulatory requirements, with emphasis on the nature, sources, and costs of compliance technologies; on cost reductions due to learning and innovation; and on organizational and strategic change.

3. Compare and contrast ex ante estimates of compliance costs with the ex post findings of carefully conducted case studies, at a level of disaggregation that would allow for testing a model that takes into account the nature of the regulated technology, the structure of the industry, the severity of the problem, and the details of the regulatory stimulus.

4. Use the results of studies of type 1, 2 and 3 to develop or improve methods of ex ante engineering cost analysis that account for learning and innovation in a reasonable way.

5. Develop a data base and models that can be used to forecast regulatory compliance levels under various circumstances.

6. Do case studies to build a data base on the effects of the institutional and design aspects of command and control regulations on the technological responses of firms to regulation.

7. Expore the possibility of fundamental new approaches to environmental regulation that create strong incentives for reducing both hazards and compliance costs. While economic incentives may be one such approach, they need further study and experimentation to determine how best to structure them. Combinations of regulatory sanctions and incentives such as noncompliance fees, "bubbles," and offsets should also be considered further.

It is important that studies in these area involve several disciplines, including engineers, economists, cost engineers, behaviorists, and regulatory specialists. Traditional static economics and traditional cost engineering have not adequately addressed the issues raised in this paper, and they are unlikely to do so alone in the future. Thus, interdisciplinary research should be encouraged.

It is not appropriate to recommend a prioritization of the research topics listed above--instead, a mix of activities is needed. Three blocks of activities appear to make up a coherent program that attacks the immediate need for better regulatory analysis, while providing the basis for long-term improvements in regulatory design and analysis. For example, topic (4) studies should begin at once, though topics (2) and (3) are logical percursors to (4), and topic (1) to topics (2) and (3). I would recommend, however, that one block of resources be devoted to "fundamental" studies on topics (1) and (7) together; another block to "applied" studies on topics (2), (3), and (4); and another block to "applied" studies on topics (5) and (6). Allocation of research monies to such blocks at a high level would avoid the tendency of short-term projects to crowd out long-term, more risky and fundamental projects when they must complete one-on-one for support.

Finally, it is important to note that a similar, if not longer list could be created for research needs and opportunities on regulatory effectiveness and benefits assessment. These are equally worthy of research support.

The analysis of technological change, or "dynamic economics," unlike static economics and classical physics, is guided by neither a maximizing principle nor a conservation law. As in many other fields that study growth and change, students of technological innovation must depend on heuristics and extensions of static concepts to guide their work. Perhaps a "non-equilibrium economics" will emerge to play the same role in guiding economic thought beyond statics as has non-equilibrium thermodynamics in guiding thermodynamics into the realm of change. In the meantime, the fact that studies of change are challenging and uncertain does not mean that change can legitimately be ignored, even in the relatively narrow field of regulatory analysis. For to ignore dynamics in human affairs is to ignore that which distinguishes us from the rest of nature--the ability to consciously change in response to our surroundings and to each other.

REFERENCES

Abernathy, William J. and Kenneth Wayne, 1974. "Limits of the Learning Curve," Harvard Business Review, September-October, pp. 109-119.

Abernathy, William J., 1978. The Productivity Dilemma, Harvard University Press, Cambridge.

Anderson, Frederick R. et al., 1977. Environmental Improvement Through Economic Incentives, Johns Hopkins University Press for Resources for the Future, Baltimore.

Ashford, N.A., C.T. Hill, et al., 1980. Center for Policy Alternatives, M.I.T., "Benefits of Environmental, Health and Safety Regulation," committee print of the Committee on Governmental Affairs, United States Senate, March 25.

Ashford, Nicholas A., and George R. Heaton, 1979. "The Effects of Health and Environmental Regulation on Technological Change in the Chemical Industry: Theory and Evidence," in C.T. Hill, ed., Federal Regulation and Chemical Innovation, American Chemical Society Symposium Series No. 109, Washington, D.C.

Ashford, N.A., G.R. Heaton, and W.C. Priest, 1979. "Environmental, Health and Safety Regulation and Technological Innovation," in C.T. Hill and J.M. Utterback, eds., Technological Innovation for a Dynamic Economy, Pergamon Press, Elmsford, N.Y., chapter 5.

Ashford, N.A., D. Hattis, G.R. Heaton, J.I. Katz, W.C. Priest, and E.M. Zolt, 1980. "Evaluating Chemical Regulations: Trade-off Analysis and Impact Assessment for Environmental Decision-Making," report by the MIT Center for Policy Alternatives to the U.S. Council on Environmental Quality and U.S. Environmental Protection Agency, July.

Ashford, N.A., G.R. Heaton, et al., 1981. The Response of Foreign Automobile Firms to U.S. Regulation, report of the Center for Policy Alternatives to the Transportation Systems Center, U.S. D.O.T., draft.

Binswanger, H.P. and V.W. Ruttan, 1978. Induced Innovation, Johns Hopkins University Press, Baltimore.

Bodde, David L., 1976. "Riding the Experience Curve," Technology Review, March/April, pp. 29-35.

Center for Policy Alternatives, M.I.T., 1981. "Methods and Considerations in Analyzing the Benefits of Environmental, Health and Safety Regulations," Rough Draft report to the U.S. EPA, February 26.

Cran, John, 1981. "Improved Factored Method Gives Better Preliminary Cost Estimates," Chemical Engineering, April 6, pp. 65-79.

DeMuth, C.C., 1980. "The Regulatory Budget," Regulation, 29-44, March/April.

Desai, M.B., 1981. "Preliminary Cost Estimating of Process Plants," Chemical Engineering, pp. 65-70, July 27.

Dewees, Donald N., 1978. "The Costs and Technology of Pollution Abatement," in Approaches to Controlling Pollution, Ann F. Friedlaender, ed., MIT Press, pp. 291-334.

Freeman, A.M., 1979. The Benefits of Environmental Improvement, Johns Hopkins University Press for Resources for the Future, Baltimore.

Grabowski, H. and J. Vernon, 1979. The Impact of Regulation on Industrial Innovation, National Academy of Sciences, Washington, D.C.

Greenberg, Edward, Christopher T. Hill, and David J. Newburger, 1979. Regulation, Market Price and Process Innovation, Westview Press, Boulder, Colo.

Hill, Christopher T., Edward Greenberg, David J. Newburger, Gilbert R. Whitaker, et al., 1975. "The Effects of Regulation on Technological Innovation in the Chemical and Allied Products Industries," Report to the National Science Foundation, Office of R&D Assessment, Volume I, Executive Summary, 16 pages; Volume II, The State of the Art, 205 pages; Volume III, Abstracts and Literature List, 500 pages; February.

Hill, Christopher, T. ed., 1979a. Federal Regulation and Chemical Innovation, American Chemical Society Symposium Series #109, Washington, D.C.

Hill, Christopher T., 1979b. "Technological Innovation: Agent of Growth and Change," in C.T. Hill and J.M. Utterback, eds., Technological Innovation for a Dynamic Economy, Pergamon Press, Elmsford, N.Y., chapter 1.

Hill, Christopher T., Richard A. Andrews, Richard Frenkel, et al., 1980. Supporting Innovation: A Policy Study, report to the U.S. EPA by the MIT Center for Policy Alternatives, EPA-560/ 12-80-002, September.

Hill, Christopher T., 1980. "The Induced Beneficial Technological Effects of Environmental Policy," paper prepared for the Environment Directorate, the Organisation for Economic Cooperation and Development, Paris.

Hill, Christopher T. and Richard A. Andrews, 1980. "Emissions Technology--Sweden," in "U.S. Automobile Regulation: An Examination of the Foreign Experience," Nicholas A. Ashford, George R. Heaton, Jr., et al., interim report to the U.S. Department of Transportation by the MIT Center for Policy Alternatives, July, pp. 3-52 to 3-54.

Hill, Christopher T., 1981. "The Role of Cost/Benefit Analysis in Environmental Policy," paper delivered to the Engineering Section, the New York Academy of Sciences, May.

Hirschmann, Winfred B., 1964. "Profit from the Learning Curve," Harvard Business Review, January-February, pp. 125-139.

Kagan, David M., 1979. *Regulations and Technical Change in the Automobile Industry*, MS Thesis, MIT, Cambridge.

Kelman, S., 1981. "Cost-Benefit Analysis: An Ethical Critique," *Regulation*, January/February, pp. 33-40.

Klein, Burton H., 1977. *Dynamic Economics*, Harvard University Press, Cambridge.

Klein, Burton H., 1979. "The Slowdown in Productivity Advances: A Dynamic Explanation," in *Technological Innovation for a Dynamic Economy*, Pergamon Press, Eimsford, N.Y., chapter 3.

Klein, Burton H., 1981. Personal Communication.

Kneese, Allen V. and Charles L. Schultze, 1975. *Pollution, Prices and Public Policy*, Brookings Institution, Washington, D.C.

Lave, Lester B., 1981. "Conflicting Objectives in Regulating the Automobile," *Science*, *212*, May 22, pp. 893-899.

Little, A.D., Inc., 1974. "Economic Impact of a Shutdown of the Polyvinyl Chloride Industry," prepared for the Society of the Plastics Industry, May.

Magat, W.A., 1978. "Pollution Control and Technological Advance: A Dynamic Model of the Firm," *Journal of Environmental Economics and Management*, 5, pp. 1-25.

McCain, R.A., 1978. "Endogenous Bias in Technical Progress and Environmental Policy, *American Economic Review*, Sept., pp. 538-546.

Merrow, Edward W., K.E. Phillips, and C.W. Myers, 1981. "Understanding Cost Growth and Performance Shortfalls in Pioneer Process Plants," RAND Corporation Report R-2569-DOE, September.

Nelson, Richard R., 1978. Comment on D.N. Dewees, "The Costs and Technology of Pollution Abatement," op. cit.

Oates, Wallace E. and William J. Baumol, 1975. "The Instruments for Environmental Policy," in *Economic Analysis of Environmental Problems*, Edwin S. Mills, ed., National Bureau of Economic Research and Resources for the Future, Inc., Columbia University Press, pp. 95-132.

Park, W.R., 1973. *Cost Engineering Analysis*, Wiley, New York.

PEDCo Environmental, Inc., 1979. "Cost Analysis Manual for Standards Support Document," prepared for the U.S. Environmental Protection Agency, Economic Analysis Branch, Research Triangle Park, N.C., April.

Peters, Max S. and Klaus Timmerhous, 1980. *Plant Design and Economics for Chemical Engineers*, 3rd Edition, McGraw-Hill, New York.

Putnam, Hayes and Bartlett, Inc., 1980. "Comparisons of Estimated and Actual Pollution Control Capital Expenditures for Selected Industries," prepared for the Office of Planning and Evaluation, U.S. Environmental Protection Agency.

Royston, Michael G., 1980. "Making Pollution Prevention Pay," Harvard Business Review, November-December, pp. 6-10, 18-22.

Schults, W.D. and A.V. Kneese, 1981. "Risk in Benefit-Cost Analysis," Risk Analysis, 1, 81-88 (1981).

Thompson, Russell G., 1979. "Economic Trends, Resource Scarcity and Policy-making," in Federal Regulation and Chemical Innovation, C.T. Hill, ed., ACS Symposium Series #109, Washington, D.C.

Uhl, Vincent, 1979. "A Standard Procedure for Cost Analysis of Pollution Control Operations; Vol. I User Guide, and Vol. II Appendices," Industrial Environmental Research Laboratory, U.S. Environmental Protection Agency, EPA-600/8-79-018a.

U.S. Environmental Protection Agency, Economic Analysis Division, 1979. "Detailed Guidelines for Analyzing Economic Impacts," in Improving Environmental Regulations; Final Report Implementing Executive Order 12044, mimeo, 4 pages.

Utterback, James M., "The Dynamics of Product and Process Innnovation in Industry," in C.T. Hill, and J.M. Utterback, eds., Technological Innovation for a Dynamic Economy, Pergamon Press, Elmsford, N.Y., chapter 2.

Vatavuk, William M. and Neveril, Robert B., 1980-81. "Estimating Costs of Air-Pollution Control Systems," a series of papers in Chemical Engineering, (10/06/08, 11/03/80, 12/01/80, 12/29/80, 01/26/81, 03/23/81, 05/18/81), pages respectively, 165-68, 157-62, 111-15, 71-3, 127-32, 223-28, 171-77.

Weaver, J.B., H.C. Bauman, and W.F. Heneghan, 1963. "Cost and Profitability Estimation," in J.H. Perry, ed., Chemical Engineer's Handbook, 4th edition, McGraw-Hill, New York.

White, L.J., 1980. "Truth in Regulatory Budgeting," Regulation, pp. 44-46, March/April.

ESTIMATING ENVIRONMENTAL COMPLIANCE COSTS FOR INDUSTRY: ENGINEERING AND ECONOMIC APPROACHES

by

Raymond J. Kopp
and
Paul R. Portney
Resources for the Future, Inc.
Washington, D.C.

CONTENTS

Page

1.0 Introduction 74

2.0 Why Estimate Compliance Costs? 75

3.0 Ex Post Estimates of Environmental Compliance Costs 77

  3.1 Survey Estimates of Expenditures 77

  3.2 Other Checks on Pollution Control Spending 82

4.0 Ex Ante Estimates of Compliance Costs 87

  4.1 The Input Cost Accounting Approach 88

  4.2 Engineering Process Models 90

    4.2.1 Overview of the Model 90

    4.2.2 Process Models and Specific Classes of Environmental Regulations 92

  4.3 Neoclassical-Econometric Models of Production Activity 98

    4.3.1 Overview of the Model 98
    4.3.2 Economic Models and the Analysis of Environmental Regulations 101
    4.3.3 Some Often Overlooked Regulatory Costs: Dynamic Impacts 105

5.0 Practical Problems with Ex Ante Compliance Cost Estimation 109

  5.1 Problems Associated with Process and Econometric Models 109

  5.2 Some Topics for Research 111

Footnotes 113

References 116

1.0 Introduction

The U.S. economy has changed in a number of ways over the last 10 years. One of the important changes has been the extent to which certain kinds of activities have come to be circumscribed by Federal regulations. These regulations extend from limitations on the discharge of air and water pollutants and permissible concentrations of harmful substances in workplaces to requirements governing the hiring and firing of employees. In both breadth and intensity, Federal regulation has become more pronounced.

But how much more pronounced? This is a difficult question to answer because we often do not know how much regulation costs affected individuals, firms, and governmental units. These costs of regulation are one--but certainly not the only--important measure of the scope and impact of regulation on the economy. One reason we lack such a measure of the cost of Federal regulation is that the expenditures necessitated by regulation do not pass through the Federal budget. That is, EPA does not install flue gas scrubbers on electric power plants or build cooling towers at these facilities to ease thermal water pollution. Rather, they require these expenditures of private firms and there is very little Federal accounting of the expenditures made by regulatees, either public or private.

This paper is concerned with the estimation of the costs incurred by the private sector in complying with Federal environmental regulation. Its purpose is not to develop new estimates of these costs or to critique in great detail existing methodologies. Rather, our primary purpose is to discuss briefly the pros and cons of existing approaches to compliance cost estimation, outline several new and more comprehensive methodologies, and discuss the problems that would be encountered in trying to put these approaches into practice.

In Section II we indicate several reasons why compliance cost information is important, and draw several semantic distinctions it is important to bear in mind when thinking about such costs. Following that, we discuss a number of ongoing attempts to estimate the expenditures in previous years on environmental regulation; we also discuss several new ways in which inferences can be drawn about prior pollution control spending. Next, in Section II, we take up the ex ante estimation of industrial compliance costs. That is, we look at ways in which prospective rather than existing regulations can

---

*Raymond J. Kopp is Fellow, Quality of the Environment Division, Resources for the Future (RFF), and Visiting Assistant Professor of Economics, University of North Carolina. Paul R. Portney is Senior Fellow, Quality of the Environment Division, RFF. The authors wish to acknowledge the very helpful comments of Margaret Slade and William Vaughan on an earlier draft of this paper. Jeff Kolb of the Environmental Protection Agency (EPA) graciously made available the data on use of tax-exempt pollution control bonds, which facilitated our analysis. Kopp acknowledges the support of the Andrew W. Mellon Foundation in conjunction with this work.

be expected to affect the private sector. In Section IV we discuss the current method of forecasting compliance costs (which we refer to as the "input cost accounting approach"), as well as several more sophisticated methodologies to determine these costs, including engineering process models and neoclassical econometric models. A final section, Section V, touches on the practical prospects for improving compliance cost estimation in the ways we have suggested.

2.0 Why Estimate Compliance Costs?

Given the difficulties in identifying and quantifying them, one might question the need for more accurate estimates of environmental compliance costs. There are three reasons it is important to know these costs. First, and most simply, cost-benefit analyses of Federal regulatory programs are impossible without accurate estimates of environmental compliance costs. These cost-benefit analyses are in turn important because, when properly done, they can assist in identifying areas where additional regulation may do more harm than good, and areas where additional regulation will improve the allocation of resources resulting from the unaided private market. Efficiency in the allocation of resources is not the only economic goal of Government, of course. Economic policy is designed to address both macroeconomic stability as well as the distribution of income. Nevertheless, efficiency in resource allocation is one very important goal, arguably the principal reason for the creation of federal regulatory agencies.

Accurate compliance cost estimates can do more than contribute to sound benefit-cost analysis, however. They can also be used to make inferences about the macroeconomic consequences associated with environmental regulation.[1] That is, compliance cost estimates can be used in a number of ways to help determine the effects of regulation on the price level, the unemployment rate, the rate of economic growth, the balance of trade, the levels of investment and productivity, and other indicators of aggregate economic activity. Thus, compliance cost estimates are essential to understanding both the allocative as well as the cylical or countercyclical effects of environmental regulation.

Finally, accurate estimates of environmental compliance costs are essential if the costs imposed by regulatory agencies are ever to be subject to the same kinds of controls imposed on the direct spending of the various departments of the Federal (and other levels of) Government. To elaborate, some students of regulation have proposed that EPA and other regulatory agencies be subjected to a "regulatory budget" that would limit the annual total expenditures each could require public and private regulatees to make (in much the same way each of these agencies is currently limited in what it can spend for salaries, rent, travel, consultants, and so forth).[2] Since no limit now exists, some critics of regulation argue, agencies have no incentive to limit their regulatory appetites and establish priorities among and within programs--in short, they have no incentive to think about new regulations in a way that is useful to society.

But if such a regulatory budget were ever to be considered seriously, one thig is clear: It would fail if there were no way to assess with some confidence the costs that regulated parties were forced to bear as a result of agencies' regulations. For it is only by adding up these costs that one could determine whether or not an agency had exceeded its regulatory budget for the year. Unlike the direct expenditure budget, there are no cancelled checks that can be tallied at the end of the year to check on total, on-budget spending. Without an accounting system maintained by the regulatory agencies, an oversight body, and/or regulatees themselves, such an accounting would be impossible and the regulatory budget virtually unenforceable.

Thus, for a number of reasons it is important to have accurate information about the costs of complying with environmental regulation. Not only is such information essential to the analysis of the allocative, distributive, and macroeconomic effects of regulation; it is also a precondition for any type of new mechanism to control the costs that regulatory agencies impose on private and public parties.

Before turning to ways these costs have been examined in the past, it is useful to discuss briefly the kinds of compliance costs referred to throughout this paper.[3] The concept of costs appropriate to a benefit-cost analysis of environmental regulations is of course social opportunity cost. That is, all the productive opportunities that are foregone throughout the economy as a result of a regulation (not just those foregone by the regulatee) must be included as costs of the regulation. These will generally be greater than, but may sometimes be less than, the expenditures made by firms in response to regulation.[4] Nevertheless, for the purposes of this paper the terms "pollution control expenditures," "pollution control costs," and "compliance costs" will be used more or less interchangeably.

We also distinguish in this paper between direct and indirect costs. By the former we mean those associated with regulation that would show up in an accounting statement--purchases of capital equipment, expenditures for the materials and energy to run the equipment, labor to operate and maintain it, and resources devoted to the recordkeeping and other administrative requirements arising from regulation. Indirect costs are also very important consequences of environmental and other regulation, but generally do not show up in the same way as direct costs. They include: (1) the diminished productivity that may result when regulations are imposed on private firms; (2) the reduction in innovative activity perhaps induced by regulation; and (3) the losses that result when regulation induces "upstream" or "downstream" changes in factor mixes that inhibit production, etc.

None of these kinds of effects will appear on a balance sheet across from an entry indicating a regulatory requirement. Nonetheless, they are very important, so important, in fact, that one of us has argued that econmetric simulations of the effect of regulation on the economy cannot be taken too seriously for the very reason that they exclude these indirect costs.[5] It is because of the importance of these costs that we suggest in a later section the use of more complicated models to determine compliance costs than have been used in the past.

3.0 Ex Post Estimates of Environmental Compliance Costs

The most important use of compliance cost estimates is probably to determine, in advance of regulation, what would be the allocative and macroeconomic effects of the proposed rule. Nevertheless, we begin with a discussion of ex post estimates of the costs of complying with existing rules and regulations. There are a number of ways of determining past compliance costs; the problems encountered in these approaches foreshadow the difficulties that will arise in estimating the expected costs of proposed rules. Most of the ex post estimates are made using surveys of affected firms.

3.1 Survey Estimates of Expenditures[6]

Considering their importance, there are surprisingly few comprehensive estimates available of past expenditures for pollution control. Sometimes the information that is available is conflicting or disparate. For example, both the Bureau of Economic Analysis (BEA) and the Bureau of Census within the Department of Commerce conduct annual surveys to determine expenditures on pollution control. Similarly, McGraw-Hill, Incorporated also surveys business annually to determine pollution abatement expenditures. Table 1 compares estimates from these three sources of actual capital investment in pollution abatement control for 1978, and estimates from McGraw-Hill and BEA of planned capital expenditures for 1980.

Table 1. Estimatated Capital Expenditures for Pollution Control (millions of dollars)

Industry	1978 ACTUAL (1) McG-Hill[a]	 (2) BEA[b]	 (3) Census[c]	1980 PLANNED (4) McG-Hill[d]	 (5) BEA[b]
Iron and steel	425	441	{793	1,069	638
Nonferrous metals	293	247		285	285
Other primary metals	-	54		-	87
Electric machinery	134	130	75	238	126
Machinery	243	111	82	196	97
Autos, trucks, parts	193	198	{140	162	311
Aerospace	45	23		30	34
Fabricated metals	137	-		189	-
Instruments	58	-		146	-
Stone	207	164	127	125	176
Other durables	190	181	186	116	199
Total durables	1,935	1,561	1,402	2,559	1,956
Chemicals	547	565	842	762	476
Paper/Pulp	274	239	342	473	300
Rubber	100	58	28	201	58
Petroleum	834	1,294	420	1,525	1,536
Food/Beverage	309	172	185	181	150
Textiles	81	29	60	110	36
Other nondurables	67	32	37	97	27
Total nondurables	2,212	2,389	1,914	3,450	2,583
Total manufacturing	4,147	3,950	3,316	6,009	4,540
Mining	511	206		109	171
Railroads	54	36		53	32
Airlines	20	15		97	13
Electric utilities	2,791	2,472		3,615	2,558
Gas utilties	60	35		61	44
Commercial	{423	{220		512	{243
Commercial & other trans.				93	
	3,859	2,974		4,539	3,161
ALL BUSINESS	8,006	6,924		10,548	7,699

---

[a] 12th Annual McGraw-Hill Survey of Pollution Control Expenditures, May 14, 1979.

[b] Gary Rutledge and Betsy O'Connor, "Capital Expenditures by Busines for Pollution Abatement, 1978, 1979, and Planned 1980," *Survey of Current Business*, June 1980.

[c] *Pollution Abatement Costs and Expenditures,* 1978, U.S. Bureau of the Census, MA-200(78)-2, U.S. G.P.O., Washington, D.C., 1980.

[d] 13th Annual McGraw-Hill Survey.

As columns 1, 2, and 3 of the table indicate, there are considerable differences among estimates, even with respect to actual or historical capital expenditures. For example, McGraw-Hill's estimate of pollution control investment in the machinery industry in 1978 is three times that of the Census Bureau, and more than twice that of BEA. On the other hand, the Census estimate for investment in pollution control by the chemical industry is about 50 percent greater than the estimates of either McGraw-Hill or BEA. BEA's estimate for petroleum refining is more than three times that of the Census Bureau, and is 50 percent higher than McGraw-Hill's reported total. Other differences in both individual industry and total estimates are clear.

Given the discrepancies among estimates of historical expenditures for pollution abatement capital, one might expect even more divergent estimates of planned future expenditures. Columns 4 and 5 of table 1 confirm this suspicion. According to McGraw-Hill, total planned capital expenditures for pollution abatement for all business in 1980 were $10.5 billion. This was 37 percent more than BEA projected based on its survey of manufacturing and nonmanufacturing firms. For the electric utility industry alone, the McGraw-Hill and BEA estimates of 1980 investment in pollution control differed by nearly a billion dollars.

There are two major reasons why these three sets of estimates diverge so. First, the Census Bureau surveys establishments or plants, while the BEA survey goes to firms. Hence, if a multidivision firm has operations in several different industries, all of its pollution control expenditures across all operations are attributed by BEA to its primary product. Thus, expenditures for pollution control in U.S. steel's paintmaking operations are recorded under "steel works" in the BEA survey. This accounts for some of the difference between BEA and Census. Second, the sample sizes used by BEA, Census, and McGraw-Hill differ. The Census Bureau surveys 20,000 plants to estimate pollution control investment in the manfuacturing sector. The Bureau of Economic Analysis surveys about 15,000 firms to prepare its estimate. McGraw-Hill, like BEA, bases its estimates on a sample of firms, yet they sample only 346--less than 3 percent of BEA's sample size. Hence, all three sources are trying to estimate national totals based on different sample sizes, composition, and definitions.

Several factors point toward possible upward bias of all three sets of estimates. Although the response rates for the McGraw-Hill and Census surveys are unknown, it is about 60 percent for BEA, of which at least some responses no doubt prove unusable. It is not unreasonable to expect that the firms that do respond to the survey are those that are spending considerable amounts on pollution abatement. If their experience is generalized to all firms in an industry, the resulting estimates will be high. This will be particularly true in industries with both large firms and small firms. Since many regulations exempt firms below a certain size, the effect of environmental rules on all small firms taken could be negligible. Yet, if a number of small firms are treated as one big firm, estimates of their expenditures may be large.

Second, some respondents can be expected to have difficulty determining which portion of capital and operating expenditures is due to pollution abatement and which portion is made to improve normal operations and increase profitability. This joint cost problem is especially difficult when new facilities are constructed or existing ones are modified. The temptation in such cases is to err in the direction of large pollution control expenditures, creating a possible further upward bias to the estimates. Finally, although there is little evidence to support such a supposition, some firms may deliberately report erroneously high numbers in an attempt to cast regulation in a bad light.

There is another problem with the BEA, Census Bureau, and McGraw-Hill estimates. Not only are they of questionable value in estimating what they attempt to estimate, but that which they do estimate may not be what we are after. This is because the totals reported in the three surveys discussed above encompass pollution control spending that arises not only as a result of Federal environmental regulation, but also spending necessitated by State and local controls, and spending voluntarily undertaken (as for good will). In terms of the distinction drawn by the Council on Environmental Quality (CEQ), the surveys discussed above report total pollution control spending but do not separate out incremental spending (due to Federal regulation). This extends not only to estimates of annual capital expenditures but also to estimates of annual operating costs.

The Census Bureau does try to eliminate one type of pollution control spending from their totals--that which results in the profitable recovery of byproducts. Their survey makes allowance for and deducts this offsetting revenue (see Item 5 in the survey and its explanation in the "specific instruction"). Nevertheless, even the Census Bureau survey lumps together pollution control expenditures made in response to local, State or Federal regulations and those expenditures made for good will. Thus, neither it nor the BEA or McGraw-Hill surveys are particularly useful in identifying pollution control costs that arise exclusively as a result of Federal environmental regulation.

Even if the three surveys did isolate expenditures made in response to Federal regulation, they would not be ideal for the tasks at hand. This is because the surveys lump together all air pollution spending, all water pollution spending, and all spending on solid waste. That is, there is no way to differentiate the effect of air pollution controls in State Implementation Plans, for example, from those arising from new source performance standards, or from controls to prevent emissions into the atmosphere of hazardous air pollutants. Although survey estimates of aggregate spending necessitated by Federal regulation would facilitate macroeconomic analysis, they would still not be useful in evaluating the allocative effects of specific regulations. For this, estimates would be needed on a regulation-by-regulation basis. It is unlikely that large-scale surveys of the sort discussed here will ever provide such detailed information.

Even when firms have been surveyed in considerably more detail, this latter problem has remained. The analysis performed by Arthur Andersen and Company for the Business Roundtable (AA/BR) is a case in point.[7] This study was billed as the most comprehensive analysis to date of the economic effects of Federal regulation on 48 major U.S. corporations. It included not only environmental regulation, but also occupational safety and health controls, affirmative action requirements, energy regulations, Federal pension and retirement restrictions, and consumer protection requirements mandated by the Federal Trade Commission.

Perhaps the most significant aspect of the AA/BR study is the methodology it employed. A conscious effort was made to isolate for the year in question, 1977, those expenditures that arose solely as a result of Federal regulation. According to AA/BR, for example, the study excluded air and water pollution control expenditures that the reporting firms would have made even had these expenditures not been required by regulation. This should make their estimates very conservative. For instance, suppose no law prohibited the discharge of substance X into the air. A law is then passed which prohibits this discharge. One would assume that any costs associated with the control of X would be counted as incremental control costs. Not so in the AA/BR study. If a firm was controlling substance X to some degree prior to regulation, those costs are netted out of total control costs in calculating the incremental cost of complying with the regulation. (Figure 1 on p. 103 illustrates the AA/BR methodology).

There are several observations to be made about the AA/BR approach. First, it does improve in a couple of ways on the survey approach taken by BEA and the Census Bureau. Not only are incremental costs distinguished from other pollution control expenditures; also, it is somewhat easier to link incremental costs to specific regulatory requirements. For instance, the report targets particulate removal under State Implementation Plans as being expensive (especially in relation to the amount removed). It also identifies the national ambient air quality standard for ozone as being expensive for the firms surveyed to comply with.[8]

Second, the AA/BR study is bedeviled by a problem that always crops up in attempts to isolate regulation-induced spending from that which would take place anyway. This problem arises because it is always difficult if not impossible to determine what a firm would have spent in the absence of a particular regulation. Since this varies from firm to firm--some would voluntarily remove much more pollution than others, for instance--it is very difficult to extrapolate from a simple sample of firms (48 in the AA/BR study) to the economy as a whole. For this reason and several others, no economy-wide estimates of regulatory burdens in 1977 were hazarded by AA/BR.

While understandable, this failure to generalize the findings from the 48 firms involved to the whole economy limits the usefulness of the AA/BR study. It makes it impossible, for example, to compare the BEA, Census Bureau, and McGraw-Hill estimates of new investment in pollution control with the figures in the AA/BR study. This is unfortunate because of the careful and conscious focus in the latter on incremental effects. This in turn makes it difficult to use the AA/BR study as a basis for any analysis of the macroeconomic effects of regulation on the economy.

What can we conclude about the use of surveys to make inferences about pollution control expenditures? Two observations seem warranted. First, while they provide some useful information, the BEA, Census, and McGraw-Hill surveys will not be useful either for micro- or macroeconomic analyses until they distinguish between expenditures necessitated by Federal regulation and those arising for other reasons. Second, since all the surveys are based on extrapolations from a sample of firms or establishments to the industry as a whole, it is important to treat the overall estimates cautiously. In fact, the problems of extrapolation were so great with the AA/BR study that no attempt was made to generalize the findings from the 48 firms involved to the economy as a whole. Some of the same problems exist with the other three surveys, of course. Finally, we should remember that even perfect surveys will give us information only about past expenditures for environmental quality management. Useful as this information may be, it does not help in ex ante analyses of regulatory impacts.

3.2 Other Checks on Pollution Control Spending

One disadvantage to all survey approaches is that they rely on firms for accurate information on pollution control spending. When firms misunderstand survey instruments, when samples are unrepresentative of the entire population, or when firms strategically mis-state true spending, economy-wide estimates of pollution control spending based on surveys may be misleading. In this section we discuss briefly two means which might be used to check on the accuracy of firms' reported estimates of pollution control spending.

As a result of the Revenue and Expenditure Control Act of 1968, the use of tax-exempt industrial development bonds (IDBs) was sharply curtailed. One use of these bonds for which their tax-exempt status could be retained was for investment in pollution control equipment. These IDBs are issued by quasi-public agencies and the proceeds of the bond sale are used by private firms to install end-of-pipe pollution control equipment.[9] The firm repays the bond holders in much the same way it would if it floated the bonds privately. Since fairly good statistics are kept on the size and composition of the market for tax-exempt pollution control bonds, it is possible to compare survey estimates of pollution control spending with actual data on the use of tax-free bonds. Tables 2-4 compare estimates based on the BEA survey of capital investment for pollution control from 1975 to 1980 with data on the actual use of IDBs on both an aggregate and industry basis.

Several interesting observations can be drawn from the tables. First, even after eliminating investment in the process change--which does not qualify for tax-exempt financing--IDBs have only been used for 43 percent of all BEA-estimated investment in end-of-pipe pollution control since 1975. In 1980, only 39 percent of end-of-pipe investment in pollution control was financed with tax-exempt IDBs. In addition, according to BEA surveys, although new investment in end-of-pipe control equipment rose every year but one from 1975 to 1980, the volume in the tax-exempt market has fallen in four of those years, the last three consecutively. Although the total number of issues has risen slightly for the last two years it is still below its level in 1975, and considerably below 1977 when 221 new tax exempt issues were brought to the market.

Equally interesting are the figures on individual industry use of IDBs. As table 3 shows, certain industries rely to a much greater extent than others

Table 2.

	1975	1976	1977	1978	1979	1980	Total
1. Total Volume of Tax Exempt Pollution Control Bonds ($\$10^6$)	2,134	2,056	2,982	2,793	2,466	2,463	14,894
2. Number of Issues	193	168	221	155	163	170	1,070
3. Average Issue Size ($\$10^6$)	11.1	12.2	13.6	18.0	15.1	14.5	13.9
4. New Investment in Pollution Control Plant and Equipment	6,549	6,762	6,939	6,924	7,143	7,699P	42,016
5. New Investment in End-of-Pipe Plant and Equipment (Including solid waste)	5,419	5,524	5,609	5,549	5,826	6,376P	34,301
6. Total capital expenditures (corporate)	113,489	121,232	137,017	153,090	176,371	195,673P	896,872
7. IDBs as a percent of end-of-line pollution control expenditures	39.4	37.2	53.2	50.3	42.3	38.6	43.4
8. IDBs as a percent of total capital expenditures	1.9	1.7	2.2	1.8	1.4	1.3	1.7
9. Total Tax Exempt Financing (adjusted by CBO study on IRBs)	30,126	34,914	46,860	49,115	48,061	53,282	262,358
10. Corporate Bonds	42,756	42,380	42,015	36,872	40,139		
11. IDBs as a percentage of tax exempt financing	7.1	5.9	6.4	5.7	5.1	4.6	5.7
12. IDBs as a percentage of corporate bonds	5.0	4.9	7.1	7.6	6.1		

Sources: Lines (1) - (3): Weekly Bond Buyer, Jan. 26, 1976, Jan. 31, 1977, Jan 23, 1978, Jan 22, 1979, Jan. 21, 1980, and Jan. 19, 1981.
Lines (4) - (6): Survey of Current Business , June 1978 and June 1980.
Line (9): Weekly Bond Buyer, Jan. 8, 1979 and Jan. 12, 1981; Small Issue Industrial Review Bonds, CBO, April 1981, p. 14.
Line (10): Federal Reserve Bulletin, April 1979, December 1980.

Table 3.

	1975	1976	1977	1978	1979	1980^P	Total
				(Millions of dollars)			
Pollution control cost--capital expenditures for end-of-line methods plus solid waste							
Electric Utilities	1336	1735	1907	1932	2183	2264	11,357
Petroleum	963	932	859	1027	1150	1296	6,227
Metal processors	889	799	791	622	724	892	4,717
Chemicals	561	577	544	476	387	398	2,943
Paper	463	411	364	215	260	234	1,947
All Other	1205	1070	1144	1277	1122	1292	7,110
Total	5,417	5,524	5,609	5,549	5,836	6,376	34,301
IDB Financing							
Electric Utilities	628	1027	1919	1558	1579	1429	8,140
Petroleum	220	261	142	83	59	117	882
Metal Processors	529	276	373	647	246	263	2,334
Chemicals	253	208	244	189	181	137	1,212
Paper	224	121	155	98	141	159	928
All Other	280	163	149	218	260	328	1,398
Total	2,134	2,056	2,982	2,793	2,466	2,463	14,894
IDB Financing as a Percent of Pollution Control Costs							
Electric Utilities	47.0%	59.2%	100.0%	80.6%	72.3%	63.1%	71.7%
Petroleum	22.8	28.0	16.5	5.1	5.1	9.0	14.2
Metal Processors	59.5	34.5	47.2	104.0	34.0	29.5	49.5
Chemicals	45.1	36.0	44.9	39.7	46.8	34.4	41.2
Paper	48.4	29.4	42.6	45.1	54.2	80.8	47.7
All Other	23.2	15.2	13.0	17.1	23.2	25.4	19.7
Total	39.4%	37.2%	53.2%	50.3%	42.3%	38.6%	43.4%

Table 4. Total Use of IDBs and Percent Distribution of Use by Industry Type (1975-80)

	Total IDBs Used ($ million)	Percent Distribution (%)
Electric Utilities	$8,140	54.7%
Petroleum	882	5.9
Metal Processor	2,334	15.7
Chemicals	1,212	8.1
Paper	928	6.2
All Other	1,398	9.4
TOTAL	$14,894	100.0%

on tax-exempt financing. For instance, during 1975-80, the electric utility industry financed with IDBs nearly 72 percent of the investment BEA estimated it made in end-of-pipe plant and equipment. By contrast, the petroleum refining industry used IDBs to finance but 14 percent of its pollution control investment. The average for the other industries for which data are available is about 45 percent. In addition, table 4 indicates that the electric utility industry accounted for more than half, 55 percent, of all IDBs issued between 1975 and 1980. This is in spite of the fact that it accounted for less than a third of all investment in end-of-pipe pollution control during this same period according to BEA.

In 1980, the average IDB carried a net interest cost of about 9.5 percent. By contrast, the average yield on long-term corporate bonds issued in 1980 was 13.5 percent. On an average-sized issue of $15 million, this means interest costs are lower by about $0.6 million per year on the tax exempt bonds. In view of the significantly lower interest firms have to pay on tax-exempt bonds, why is it that less than half of all estimated investment in end-of-pipe pollution control in 1980 was financed by IDBs? Could this be a sign that firms exaggerate when responding to the BEA capital expenditure survey? Do the IDB figures give a more accurate picture of investment in pollution control? In spite of the temptation to draw such a conclusion, there are several reasons to believe that tax-exempt bonds would never be used to finance all end-of-pipe investments in pollution control.

First, the tax code restricts the use of IDBs to air and water pollution control--they can not be used to finance investments that will reduce the generation of solid waste. Thus, from line 5 in table 2 would have to be subtracted solid waste expenditures before one could get an accurate picture of actual IDB use relative to maximum possible use. The solid waste expenditures to be deducted, however, are small in comparison to end-of-pipe capital spending for air and water pollution control--in 1980 they amounted to $566 million, or about 9 percent of end-of-pipe spending. Thus, one must look elsewhere to explain the large amount of capital spending on pollution control that does not make use of the tax-exemption for IDBs.

Of course, firms may elect to finance capital expenditures (for pollution control or otherwise) in many different ways. For instance, one reason why the petroleum industry may have relied very little on tax-exempt bonds to finance pollution control (only 14 percent between 1975 and 1980) may have been their favorable profit picture over this period, particularly during 1977-80 when they financed only about 7 percent of pollution control investments with tax-exempt bonds. This may also explain the relatively intensive resort to the IDB market by electric utilities, since they have not done well as a whole over the last 5 years.

Finally, there are other impediments to the use of tax-exempt bonds that limit their use. In some cases, it may simply be that a pollution control investment is too small for a firm to go to the trouble and expense of securing an underwriter for the bonds, helping the authorized pollution control financing agency to put together the package, and marketing the bonds. Rather, it may find it expedient to install the equipment and skip the favorable tax advantage.

In other cases additional limitations on the use of IDBs may reduce their use. For instance, the Internal Revenue Service (IRS) forces firms to deduct from the amount of the investment to be financed the value of any materials that may be recovered in the waste stream, but IRS does not allow the costs of this recovery to be subtracted from this value. Thus, if sulfur will be recovered when a scrubber is installed, the market value of the sulfur must be deducted from the capital cost of the scrubber even though it may not be economic to recover the sulfur from the scrubber sludge. Similarly, IRS requires firms to deduct from the amount of investment to be financed the interest earned on the capital which is saved when bonds rather than retained earnings are used to finance pollution control. In other words, if the assumed rate of interest is 12 percent, IRS automatically reduces the amount that can be financed via IDBS by 12 percent. This provision also has an obvious effect on the volume of tax-exempt financing and drives a wedge between investments that would appear to qualify and those which are actually made using IDBs.

All this is not to deny the possibility that firms knowingly or unknowingly exaggerate investment in pollution control when they respond to the BEA, Census Bureau, McGraw-Hill, or other surveys. They may, and this would explain some of the difference between the BEA estimates and the volume observed in the market for tax-exempt IDBs. Nevertheless, as we have pointed out there are other important reasons why we would never expect all investment in pollution control equipment, or even all qualifying investment, to be financed using tax-exempt IDBs.

The preceding discussion raises an interesting issue. If firms currently have little or no incentive to accurately reveal pollution control expenditures, might they be given one? In other words, could a mechanism be devised that would at least bound the apparent incentive of firms to exaggerate pollution control spending?[10] The final "check" on estimates of pollution expenditures we discuss goes to this point.

To understand this approach it is important to note the potentially conflicting motives which a firm may face. On the one hand it may wish to exaggerate the current and future costs it will incur to comply with environmental regulations. By doing so, the firm may give impetus to efforts to "reform" regulation so as to diminish its burden on the public and private sector. At the same time, this firm may have an incentive to understate to a different group--its stockholders--the compliance costs it will face in the future. If future compliance costs were thought to be large, after all, the firm would not be as good an investment as it would if these future burdens were small.

In fact, upcoming liabilities that may reasonably be expected to result from environmental and other regulations must be identified in the 10K report that each firm must file with the Securitis and Exchange Commission each year. Several prominent firms have been penalized by the SEC for failing to report accurately these liabilities.[11] It is reasonable to inquire, then, whether these 10K reports might provide useful information on pollution control spending. The answer would appear to be that while such reports may be of some use in determining future (or ex ante) compliance costs, they will probably be of little use in determining past spending. It is not their purpose to present information on prior environmental expenditures--this information will be available from the firm in other forms. And the firm would appear to have the same incentive to exaggerate prior environmental spending in reporting to stockholders as it was when responding to surveys.

The SEC reporting requirement might be used in an attempt to create "incentive compatibility" in estimating future costs, however. Suppose a firm were required to report on its 10K filing to the SEC the same estimates of future environmental compliance costs it provides to EPA during the period a proposed regulation is being considered. This might temper somewhat a firm's inclination to exaggerate those expected compliance costs. The larger the estimate they made, the less good the firm would look to current and potential stockholders. While such a consistency requirement has problems of its own,[12] it might help to reduce any exaggeration that currently takes place in responding to surveys on environmental control expeditures. As suggested above, however, such an approach is more relevant to the ex ante estimation of control costs than it is to estimates of spending in previous years. It is to these methods of ex ante cost estimation that we now turn.

4.0 Ex Ante Estimates of Compliance Costs

As we indicated above, it is just as important to have accurate estimates of the expected costs of proposed regulations as it is to know how much is being spent as a result of existing rules. In this section we turn our attention to methods of ex ante estimation of environmental compliance costs. Here we try to do more than discuss the current methods of ex ante estimation, the most important of which we refer to as the "input cost accounting approach." We also discuss in some detail the way that two additional methodologies could be applied fruitfully to the estimation of expected compliance costs. The first methodology involves the use of what are referred to as engineering process models; the second makes use of neoclassical econometric models of the production process.[13]

4.1 The Input Cost Accounting Approach

One way to determine the expected costs of a proposed regulation is to ask the firms, individuals, and governmental units likely to be affected by it. Alternatively, one could rely upon the regulatory agency (EPA in the case of environmental regulation) or its contractors to provide such estimates. Since both regulators and regulatees generally use the same approach to estimate costs (although often with different assumptions), that approach is discussed in some detail here.

As its name implies, the "input cost accounting approach" (or ICAA) consists of two steps. First the estimator determines what additional inputs will be required by the regulation under consideration. Typically those will include capital (as in a flue gas scrubber or electrostatic percipitator), labor (to conduct tests of new chemicals, for instance), natural resources (limestone to inject into flue gases in a scrubber), and energy (which is required to operate all capital-intensive pollution control equipment). Alternatively, if a regulation required a source to burn low- rather than high-sulfur coal, the additional cost of the cleaner coal would be entered as a cost of the regulation. The second stage involves the attribution of costs to these added input requirements, both now and in the future, since at least one concern is with the present discounted value of all future incremental costs attributable to the regulation in question.

Not only must these costs be projected for all existing sources under the ICAA, but a projection must also be made about new sources that eventually will be subject to regulation. In the case of chemical regulation, of course, some estimate must be made of the number of new chemicals that will be introduced and hence subjected to premanufacturing notification and testing. The number of chemicals making it through the process times the cost per chemical would provide an estimate of the increased direct input costs arising from certain chemical regulations.

In some cases--typically in EPA cost estimates--a "model plant" approach is followed. That is, rather than attempt to estimate what will be required in the way of additional inputs at each existing facility by some proposed regulation, one or more model plants are selected which are taken to be representative of other plants in an industry. The ICAA is then used to determine compliance costs at this plant(s), and this cost is then multiplied by the number of average or model plants in the industry to arrive at total incremental cost. While this saves time and money during the cost estimation stage, it can easily create other problems.

The most obvious of these problems comes in determining what is a model plant. This choice has in the past led to both under- and overestimation of actual compliance costs. In some cases, the model plant has been taken to be one of the most modern and advanced in the industry. It is occasionally the case, in fact, that this plant will have already installed some pollution control equipment prior to regulation. This means that additional input requirements at this facility may be small; however, to generalize these small additional incremental costs to other plants in the industry where "pro bono" or anticipatory pollution control has not taken place can lead to substantial underestimates of actual compliance costs.

On the other hand, the model plant variant of the ICAA can lead to over-estimates of compliance costs as well. This can result from the same circumstances described above. For in that case, the pollution control equipment installed prior to the regulation should not be counted among the incremental costs attributable to regulation. Only the additional costs, if any, of meeting the regulation are relevant here. Yet in the case of certain industry responses to the BPT effluent guidelines EPA apparently included in their cost estimates even the equipment that had been installed prior to the regulations. That clearly leads to an overestimate of true environmental compliance costs.

There are other problems with the ICAA as well. Even though an attempt is often made to foresee new technological advances in pollution control, this foresight can never be perfect. Hence, when a new innovation makes pollution control less expensive, actual compliance costs will fall relative to the original estimates. For example, some now believe that fluidized-bed combustion now has or soon will have the ability to lower considerably the costs of sulfur removal from coal-fired industrial and utility boilers. If so, the estimates of the costs of meeting the performance standards for new sources which EPA established in 1979 may be exaggerated.

In addition to technological innovation, compliance cost estimates may exceed actual costs because of what one of us has elsewhere called regulatory innovation.[14] These regulatory innovations are best exemplified by EPA's so-called "bubble" and "offset" policies under which one source of pollution in a plant or area can increase its pollution provided that another source makes an equivalent or greater reduction in its discharges of that same pollutant. Such regulatory innovations are significant because they enable polluters to meet given discharge goals in the least expensive way possible. This means that compliance cost estimates based on cleanup at all sources will exaggerate true costs so long as sources can "buy up" equivalent reductions elsewhere at less expense. Thus, these kinds of flexibility-enhancing reforms will reduce compliance cost estimates based on the ICAA.

A final difficulty with the ICAA is the open-endedness of some of the regulations for which cost estimates must be made. Consider the example mentioned above of new source performance standards for coal-fired utilities. After it was decided how much the new standards would cost a "typical" plant, it was also necessary to estimate how many new plants would be built. Yet this is no simple matter. First, this depends on the rate of growth (or decline) of demand for electricity, something which the utilities themselves have proved to be less than prescient in estimating. Not only are tastes and prices variant, but estimating future demand is also difficult because the rate of adoption of energy conservation practices and alternative sources of energy is difficult to foresee.

Moreover, the number of new plants is not only dependent on exogenous factors like those below. It may also depend to some extent on the very regulations being analyzed. That is, if environmental controls on new plants are significantly more stringent than those on existing sources, new plants may cost so much more that there are fewer of them. Thus new source controls may affect both cost-per-plant and the number of plants. While important, this effect is very difficult to estimate because we cannot observe the plant construction activity that would take place in the absence of new source controls.

For all these reasons, then, the ICAA is flawed. It is understandable as a first order response to the new task of compliance cost estimation, and will continue to be used for quick approximations of compliance costs. But its obvious and subtle limitations point toward the need for a more sophisticated method of estimating compliance. Ideally, such a method would not only provide information about direct compliance costs--that is, additional labor, capital, natural resources, and energy--but would also make possible the identification of at least certain of the indirect costs, as well. These latter costs may include changes in the optimal use of factors both upstream and downstream from the point at which regulations have their initial impact.

The two approaches we discuss next, in more technical detail than in the discussion so far, have the characteristic that they can shed some light on both the direct and indirect costs of regulation. Each of these approaches employs well established modeling methodologies to examine the impact of Federal regulation on production activities. The first approach relies exclusively on engineering data and the physical laws of energy and material transformation. The second approach is founded on the neoclassical-economic theory of the firm and employs this theory in conjunction with economic data and econometric techniques to analyze characteristics of production activities. Neither of these approaches has been extensively employed to examine compliance cost; however, in the following sections we show how these approaches can be developed into useful compliance cost tools, potentially superior to those previously discussed.

4.2 Engineering Process Models

4.2.1 Overview of the Model

The engineering process model is a strictly engineering approach to modeling a production activity, and the impact upon that activity which a proposed environmental regulation can have.[15] As the name implies, this approach decomposes a specific production activity (such as the production of iron and steel) into identifiable engineering processes--each process associated with a specific, well-defined task. Normally, each task can be accomplished by a variety of process configurations which are differentiated on the basis of inputs and the engineering efficiency of the process. The process modeler first determines the sequence of tasks to be performed as required by a particular production activity, and then assembles the alternative processes capable of accomplishing each task. Naturally, the output of one task becomes the input of a succeeding task; thus, internal consistency among the process alternatives must be maintained to insure that a fully specified

To find the long-run cost function corresponding to (25) we make use of the envelope theorem in economic theory. For any given level of output and variable input prices there is a unique level of x that will minimize all costs. If x is set at this equilibrium level, denoted x*, then the firm is in full long-run equilibrium with respect to all factors of production and the corresponding long-run cost function is given by (27).

$$c^* = c(p_v, y, \hat{x}) + p_{\hat{x}}\hat{x}^* \qquad (27)$$

where: c = minimum total cost

$p_{\hat{x}}$ = a price vector for the quasi-fixed inputs

If we allow all input prices (both variable and quasi-fixed) and output to vary we can generate a set of short-run cost functions. The envelope of all these short-run functions, which traces the locus of minimum long-run total cost, is the long-run cost function depicted by equation (27). The long-run cost function (27) is associated with a set of long-run factor demand functions for both variable and quasi-fixed inputs, enabling a companion long-run examination of regulatory impacts.

In the partial static equilibrium model the short-run and long-run equilibriums are two distinct states of the dynamic production activity; and the transition between these two states is neither explained nor observed. There exists a second class of dynamic models which explicitly consider the adjustment from a short-run partial equilibrium to a long-run full equilibrium. This model explains the process of adjustment on the basis of internal adjustment costs.[32] Paralleling the partial static equilibrium model, the internal cost of adjustment model also dichotomizes inputs into variable and quasi-fixed categories. The variable factors can be adjusted at zero cost to the firm, while the quasi-fixed factors can only be adjusted at positive cost. The faster the rate of adjustment, the greater the cost.

The internal cost of adjustment model depicts not only short-run and long-run equilibriums but also the dynamic path of quasi-fixed factor adjustment and an expression for the adjustment costs themselves. In general, adjustment costs are found to be a function of the changes in quasi-fixed factor stocks, the levels of output, the level of quasi-fixed factor stocks, and the prices of variable inputs as depicted by equation (29).

$$\tilde{c} = \tilde{c}(\hat{x}, \Delta\hat{x}, y, p_v) \qquad (29)$$

where: $\tilde{c}$ = the cost of a given change in the levels of quasi-fixed factors per unit of time.

$\Delta\hat{x}$ = the change in quasi-fixed factor stocks per unit of time

$\hat{x}, y, p_v$: as previously defined

If a dynamic internal cost of adjustment industry model was estimated, impacts on adjustment costs of regulations which affect levels of quasi-fixed stocks could be determined. It is important to point out that these adjustment costs are incurred in addition to the static direct and indirect costs discussed previously. The lower the speed of optimal quasi-fixed stock adjustment, the greater will be the internal adjustment cost of a change in quasi-fixed stocks mandated by regulation. Industries with typically low speeds of adjustment include: textile mill products; lumber products; stone, clay, and glass products; electrical machinery; non-electrical machinery; petroleum refining; and primary metals.

Probably the most important dynamic impact a regulation can have would be to affect technological advance and innovation diffusion. Since firms must make research and development decisions in a world of imperfect foresight and uncertainty, it is not clear whether such an impact would result in a private (or social) loss or gain. It is quite conceivable that a particular regulation could serve to speed up the adoption of a highly efficient innovation or could just as conceivably forestall such adoptions. Unfortunately, the neoclassical-econometric model can provide little useful information in this regard since it does not presently incorporate a well-developed theory of technological advance or innovation diffusion.

5.0 Practical Problems with Ex Ante Compliance Cost Estimation

In the preceding sections we have discussed three approaches to the problem of ex ante compliance cost estimation; these are 1) the input cost accounting approach, 2) the engineering process model, and 3) the neoclassical econometric model. The practical problems associated with the input cost accounting approach have already been discussed in some detail and we shall not elaborate further on them. Our intention in this section is to examine the problems associated with the process and econometric model approaches to compliance cost and to suggest some avenues of future research.

5.1 Problems Associated with Process and Econometric Models

There can be no doubt that the engineering process model is an extremely useful tool for the ex ante analysis of environmental regulation. The model's ability to identify and accurately account for indirect costs and the phenomena of residual switching serve to distinguish it from the more crude input cost accounting methods. However, the model does have some inherent weakenesses and problems of implementation.

The major weakness of the process model is its lack of a time dimension. This timeless character of the model implies that all production activities occur instantaneously and that alterations in these activities (for example, process changes resulting from regulation) also occur immediately and costlessly. Moreover, the model is poorly equipped to deal with technological change and the diffusion of innovation; thus, it is largely unsuitable for analyses of regulatory impacts on the process of innovation.

The major implementation problem associated with the process model is cost. At the present time ~~only a~~ handful of process models exist which are capable of undertaking the types of compliance cost estimation suggested in section IV. The small number of such models is a direct result of the enormous effort which must be undertaken to construct a credible model. Upon completion of the model there still exists the cost associated with model maintenance which would include periodic updates of the technology matrix to incorporate new processes and changes in the structure of the industry the model is designed to depict. Finally, the high degree of specificity in a credible model implies that the model construction, maintenance, and results are not easily generalizable to other production activities; and thus, numerous self-contained models must be constructed to encompass the industrial sector of a modern economy.

The practical problems of process models are faily well understood since we have experience (albeit, minimal experience) in the construction and use of such models for the analysis of environmental regulation. On the other hand, the neoclassical econometric approach to compliance cost estimation is still in its formative stages, and thus we have little practical experience with the methodology. Two studies do exist which employ the formal neoclassical model in the analysis of environmental regulation. The first, Kopp [1980], studied the relationship between levels of residuals discharges and measures of technical efficiency in the U.S. electric power industry; the second, Pittman [1981], examined the impact of environmental regulation on the cost structure of paper mills. Unfortunately, the limited nature of these studies provides only a partial understanding of the problems to be faced if the econometric model approach is to be employed on a large scale to estimate ex ante compliance cost.

One practical limitation of the econometric modeling approach is clear--it is data-intensive. The quantity of data required will depend upon the level of technological disaggregation (i.e., 4, 3, or 2-digit Standard Industrial Code designations and plant, firm, or industry organization) dictated by the analysis. But regardless of the aggregation, the model will require the prices and quantities of all inputs consumed and marketable outputs produced plus estimates of residual discharges. Collecting the input and output data will be a costly task in itself; however such data do exist and have been routinely collected and used by econometricians to study production activities for some time. The task of collecting the residual discharge estimates poses a more uncertain cost. For some sectors of the economy the task will be quite straightforward since residual discharge estimates are readily available; the obvious example is U.S. steam electric generation, where residual discharge estimates have been collected for several years. For other industrial sectors EPA estimates may have to be employed.

The potential advantages of the econometric approach make it a reasonable alternative to the process model for ex ante compliance cost estimation. Aside from the initial data collection effort, the cost of econometric model construction, estimation, and maintenance is miniscule when compared to that of the process model. Moreover, the econometric model can be given a time dimension permitting one to examine the adjustment cost associated with a regulation in a dynamic setting. Finally, properly designed econometric models of industrial activity mesh well with other economic models used for policy analysis, such as large scale macroeconometric models.

The major practical problem associated with the econometric approach is its reliability. Past experience with process models has shown that they provide reasonably good approximations to actual engineering activities and can be expected to perform adequately in the complex analysis of compliance cost. Econometric models, on the other hand, do rather well in depicting factor demand, but can they reliably forecast compliance cost? The results of econometric models are sensitive to technological and input aggregation and to model misspecification, but even under ideal aggregation conditions and proper specification it is unclear whether the complexity of firms' adjustments to regulation can be adequately captured and predicted by a model which is intended only as a summary of major causal forces. Unfortunately, we have little practical experience with econometric models incorporationg discharge data upon which to base a judgment concerning the usefulness of the underlying econometric methodology.

5.2 Some Topics for Research

In the body of this paper we have asserted that the ex ante analysis of compliance cost can be improved if process models and/or econometric models are used instead of, or in conjunction with, the input cost accounting approach. Given our claim, a logical research strategy would be to establish an empirical test of the assertion. Such a test would simultaneously provide insight regarding the credibility of our proposals and would also generate experience in using process and econometric models which may uncover previously unknown practical problems or advantages.

Considering first the process model approach, it seems reasonable to circumvent the construction stage and use one of the currently available off-the-shelf models as a guinea pig. The research plan would involve choosing a particular regulation or a set of regulations to be analyzed. The process model would then be configured in a preregulation base case environment and solved. Next the model would be reconfigured in the postregulation environment and resolved. The types of compliance cost analyses discussed in section IV would then be executed. As a test of the model's validity one could choose a regulation already in place where the ex post cost data on hand are assumed to be of high quality. Using the process model we would then perform an ex ante analysis and determine how well the ex ante estimates compared to the actual ex post cost.

A test of the econometric approach is considerably more complicated than the process model. Since high quality econometric models of the kind required for ex ante estimation do not currently exist, a test methodology similar to the process model would first require the construction of a suitable econometric model. The cost of this initial construction, including data collection, can be expected to be quite high. Moreover, even if such a model were constructed and tested, we would not be able to determine the differential impact on the quality of the results emanating from poor model construction or from an underlying inadequate methodology. As we stated above, it is the econometric methodology which is really at issue and which we seek to test, not a specific model. Thus before any wholesale testing of econometric models begins, a plan to evaluate the econometric methodology must first be devised.

FOOTNOTES

1. For a review and discussion of the macroeconomic effects of environmental regulation, see Peskin, Portney, and Kneese [1981].

2. See DeMuth [1980] for the most comprehensive discussion of the pros and cons of the regulatory budget.

3. For a fuller discussion of these issues see Peskin, Portney, and Kneese [1981].

4. See Portney [1981].

5. Ibid.

6. This section draws largely on material presented in Portney [1981].

7. See Andersen [1979].

8. Ibid., p. 26.

9. For a discussion of the allocative inefficiencies that result from tax-exempt financing of pollution control, see Peterson and Galper [1975].

10. For an analysis of such mechanisms, see Sonstelie [1981].

11. For instance, see Securities and Exchange Commission Administrative Proceeding File No. 3-5936. See also Salpukas [1979].

12. See Sonstelie [1981].

13. For a discussion of other possible uses of these kinds of approaches, see Vaughan [1978].

14. See Portney [1981].

15. An excellent description of the process model approach and its applicability to environmental regulation can be found in Russell and Vaughan [1976].

16. We have taken some liberty with the notation used to describe the process model in order to utilize one set of notation consistently throughout the paper.

17. Technical efficiency is a concept attributed to Farrell [1957]. Its only known application to the case of environmental regulation is found in Kopp [1980]. A full description of Farrell's early contribution and several generalizations to it are found in Kopp [1981].

18. A methodology for analyzing both direct and indirect impacts of environmental regulation using an econometric model is found in Kopp and Smith [1981].

19. In this case we would subtract from the value of the model (6) objective function the value of the tax $t'y_r$, in order to perceive how the actual costs of production net of the tax were altered by the imposition of the tax. Naturally, if we were concerned with total private compliance cost including the tax, $t'y_r$ would remain in the calculated value of the objective function.

20. If in the preregulation environment it was profitable to recover marketable byproducts we would want to make sure that the base case objective function of model (2) included $p_r y_{qr}$.

21. We should point out that if the process model is characterized by constant returns to scale and further that it can utilize any quantity of inputs at a fixed price without limit, it will tend to expand production infinitely. In actual applications one would normally restrict the quantity of capital the model can employ.

22. These conditions are found in Diewert [1974].

23. See Shephard [1953].

24. A formal and most useful proof is contained in Diewert [1974].

25. Unfortunately, the econometric model is incapable of examining the regulatory impact of a required process adoption, since it does not identify the individual processes.

26. Since in both the preregulation and postregulation environments there are no costs to a firm for its pollution, the firm faces no constraints on its polluting behavior. Without such constraints the economic model of production is incapable of determining how the residual discharges will change with a given change in the price of factor inputs.

27. Discussions of allocative efficiency can be found in Farrell [1957] and Kopp [1981].

28. A full solution to this problem can be found in Kopp and Diewert [1981].

29. See Kopp and Smith [1980] for a theoretical discussion of these issues.

30. Of course, if the econometric model is estimated with short-run data then it will tend to overestimate the long-run effects.

31. The model is fully described in Brown and Christensen [1981].

32. See Berndt, Fuss, and Waverman [1977] for a more detailed discussion.

REFERENCES

Andersen, Arthur and Company, [1979], "Cost of Government Regulation Study," for The Business Roundtable, Executive Summary.

Berndt, E. R., M. A. Fuss, and L. Waverman, [1977], "Dynamic Models of the Industrial Demand for Energy," Electric Power Research Institute, Technical Report #EA-580.

Brown, R. and L. Christensen, [1981], "Estimating Elasticities of Substitution in a Model of Partial Static Equilibrium: An Application to U.S. Agriculture 1947-74," in Measuring and Modeling Natural Resource Substitution, edited by E. R. Berndt and B. C. Field, Cambridge, Mass.: MIT press, forthcoming.

DeMuth, C., [1980], "Constraining Regulatory Costs - Part II: The Regulatory Budget," Regulation, Mar./Apr., pp. 29-44.

Diewert, W. E., [1974], "Applications of Duality Theory," in Frontiers of Quantitative Economics, Vol. II, edited by M. D. Intriligator and D. A. Kendrick, Amsterdam: North-Holland Publishing Co.

Farrell, M. J., [1957], "The Measurement of Production Efficiency," Journal of the Royal Statistical Society, Series A, general, 120, part 3, pp. 253-81.

Kopp, R. J., [1980], "Energy, Residuals and Inefficiency: An Engineering Econometric Analysis of Environmental Regulations," in Advances in the Economics of Energy and Resources, edited by J. R. Moroney, Greenwich, Conn: JAI Press.

________, [1981], "The Measurement of Productive Efficiency: A Reconsideration," Quarterly Journal of Economics, forthcoming.

________ and W. E. Diewert [1981], "The Decomposition of Frontier Cost Function Deviations into Measures of Technical and Allocative Efficiency," Resources for the Future Discussion Paper D-75.

________ and V. K. Smith, [1980], "Environmental Regulation and Optimal Investment Behavior," Regional Science and Urban Economics, vol. 10, pp. 211-24.

________ and ________, [1981], "Productivity Measurement and Environmental Regulation: An Engineering Economic Analysis," in Productivity Measurement in Regulated Industries, edited by T. Cowing and R. Stevenson, New York: Academic Press.

Peskin, H. M., P. R. Portney and A. V. Kneese, (eds), [1981], Environmental Regulation and the U.S. Economy, Baltimore: Johns Hopkins University Press for Resources for the Future.

Peterson, G. E. and H. Galper, [1975], "Tax Exempt Financing of Private Industry's Pollution Control Investment," Public Policy, vol. 23, no. 1, pp. 81-103.

Portney, P. R., [1981], "The Macroeconomic Impacts of Federal Environmental Regulation," in Environmental Regulation and the U.S. Economy, edited by H. M. Peskin, P. R. Portney, and A. V. Kneese, Baltimore: Johns Hopkins University Press for Resources for the Future.

Russell, C. S. and W. J. Vaughan, [1976], Steel Production: Processes, Products, and Residuals, Baltimore: Johns Hopkins University Press for Resources for the Future.

Salpukas, A. [1979], "U.S. Steel Disclosure Criticized," Wall Street Journal, September 28.

Securities and Exchange Commission Administrative Proceeding File No. 3-5936, [1980], "In the Matter of Occidental Petroleum Corporation."

Shephard, R. W., [1953], Cost and Production Functions, Princeton: Princeton University Press.

Sonstelie, J., [1981], "Economic Incentives and the Revelation of Compliance Costs," prepared for the Council on Environmental Quality, January.

Vaughan, W. J., [1978], "Process Analysis for Environmental Quality Management Modeling: General Considerations and a Practical Example," Journal of Environmental Management, vol. 7, pp. 101-123.

Low- or Non-Pollution Technology Through Pollution Prevention

an overview

Low- or Non-Pollution Technology Through Pollution Prevention

Contents

Chapter | Page

FOREWORD i

1. INTRODUCTION 1

2. PERSPECTIVE ON INDUSTRIAL POLLUTION PROBLEMS 4

3. CONCEPTS AND PRINCIPLES OF LOW- AND NON-POLLUTION TECHNOLOGY 9

4. MANAGING TRANSITION TO CONSERVATION TECHNOLOGY 12

5. COST/BENEFIT EVALUATION 19

6. EXAMPLES OF LOW- OR NON-POLLUTION TECHNOLOGY .. 23

7. CONCLUSIONS AND RECOMMENDATIONS 31

Prepared by
3M Company for
The United Nations Environment Programme,
Office of Industry and The Environment

Foreword

The development process required to satisfy human needs involves changes. It is now understood that these changes need not be destructive of our life-sustaining system and of our resource base.

A major role in achieving rational use of the world's resources is reserved for industry, with its vast experience in producing useful products out of natural materials, with its ability to utilize many talents for innovation, and with its efficient organizational structure and conceptual abilities.

All of these strengths can be focused to help provide sustainable social and economic development and a better standard of life in harmony with the environment.

A willingness to help achieve this goal has been shown by the many business organizations that have cooperated with the United Nations Environment Programme in its efforts to review the environmental aspects of key industrial sectors and to offer relevant management guidelines.

Environmental management calls for integrating environmental factors into the decision-making process of development when selecting the scale, site locations and technologies of industrial activity. It is based on the necessity for us to assess the impact of these factors on the physical environment, social environment and economic environment.

Although repair to existing environmental damage will continue to be necessary, efficient environmental management in industry requires the adoption as far as possible of a preventive strategy.

Environmental problems are a reality, and some level of government regulation is a necessity. In complying, a preventive strategy consumes the infinite resources of intelligence and reasoning instead of the finite resources of energy and material goods.

It is a happy coincidence that, quite frequently, the industrial processes and practices that are environmentally sound also are those that are the least wasteful of finite resources.

The 3M Company and its vice president of environmental engineering and pollution control, Dr. Joseph T. Ling, came out early in support of pollution-prevention policies, showing the economic appeal of this approach as well as its environmental advantages.

In this booklet, which 3M prepared for UNEP, the wisdom gained in many years of work toward a better industrial environment at lower cost is presented. The lesson is striking. I am convinced that the booklet will be welcomed by friends of industry and of the environment all over the world, and that it will be used extensively in convincing many additional managers that, indeed, Pollution Prevention Pays.

Dominique Larre
Director
Industry and Environment Office
United Nations Environment Programme

Chapter One

Introduction

In a world of finite resources, it has become increasingly apparent that not only lifestyle but perhaps even life itself may depend eventually on the establishment of a conservation-oriented society.

This society should be based on "the practical application of knowledge, methods and means" to plan and manage human activities "so as — within the needs of man — to provide the most rational use of natural resources and energy, and to protect the environment."[1] Wastefulness, on the other hand, "is the irrational use of more than necessary resources to fulfill human needs and objectives."[2] This concept is being expressed in different forms in a number of countries. It represents a trend ratified and encouraged at a high-level meeting of 26 nations of the United Nations Economic Commission for Europe in January 1980 in Geneva, Switzerland.

The conserver approach recognizes that developing nations want to raise their living standards, and developed countries want to maintain and enhance theirs. To achieve either goal requires additional economic growth which includes industrial production and expansion and the consumption of resources. Production creates pollution, which is an overstress of the environment. Because pollution actually is that portion of resources which cannot be used fully with current technology, excessive pollution is a wasteful use of resources. In the conserver society, the objective is to reduce or eliminate this overstress and waste. It is a goal which can be achieved if planning begins early and is thorough.

A low- or non-pollution technology system (also called resource-conservation-oriented technology or low- or non-waste technology) is the cornerstone of this conserver society. The concept, viewed in the broad sense, covers not only production but also product use, energy, raw materials and waste disposal, as well as matters relating to protection of the environment.

It is what the International Labour Organization (ILO) has called "a technology which is appropriate to meeting all these needs within the constraints of a sustainable resource base and one which is compatible with one's culture."[3]

In Step With Requirements

The purpose of introducing low- and non-pollution technology on a large scale is to develop production in step with the growing requirements of mankind, including environmental needs, and to make rational use of natural resources and energy. "Environmental" and "development" therefore are not necessarily in conflict. In fact, "development" means total human and social development in which the key factors are not primarily economic, but are human and social needs — including job creation, enrichment and satisfaction. These needs also include safe water to drink, clean air to breathe, fertile land on which to grow food, a healthy shelter to protect one from the elements and a basic health service to combat disease.

A similar observation was made at the United Nations Economic Commission for Europe seminar, "Non-Waste Technology and Production."[4] "Non-waste technology," it was concluded at the meeting, "is of great social importance both for the level of the national economy and the creation of industrial potential. Scientific and technological progress is unthinkable without taking into account its effect on the environment and the attendant social consequences."

These considerations traditionally have related to the application of pollution control equipment which is costly in terms of manpower, money and natural resources. The low- and non-pollution approach is to eliminate the causes of pollution before having to spend money and resources to clean up afterward. It also means learning to create resources from pollution.[5]

Briefly, the concept is based on an awareness that the environment cannot be considered independently of other factors, including consumption of energy and resources, and the economy of a country. From the environmental point of view, it means using a minimum of resources to achieve the objectives and to create a minimum of pollution. Unfortunately, these goals are unlikely to be met under laws and regulations which emphasize conventional pollution controls, that is, end-of-the-pipe pollution-removal facilities. Conventional controls are limited to pollution created in the manufacturing process and cannot be extended beyond the plant gate to deal with product-use pollution. To solve a product-related problem requires a preventive approach, such as replacing toxic components with non-toxic substitutes that do away with the problems without requiring any action by the product user. This aspect becomes more of a factor in environmental planning as developing and developed nations alike pay increasing attention to user pollution, and enact measures such as the U.S. Toxic Substances Control Act, and the 6th Amendment of the European Economic Community's Dangerous Substances Act.

Conventional controls also do not relate to "the immutable Law of Conservation," a U.S. industry-government seminar on alternative technologies was told. "You can change the form of material, but it does not disappear. Purifying wastewater creates sludge. Burning chemical wastes creates particulate matter. Both residues constitute pollution and disposal problems of their own. This often is overlooked."[6]

The meeting also was told that the Law of Diminishing Returns is particularly strict in its environmental applications: "Resource requirements, and eventually the cost, of pollution removal increase exponentially as removal percentages rise. Eliminating the final traces of pollution can create a pollution problem tenfold greater than that which was eliminated." In addition, there simply are not enough financial resources to meet all of the critical needs of society. Where and when possible, we must adopt the less costly alternative of reducing or eliminating pollution sources in the first place. This approach also happens to be environmentally sound. The pollution-prevention approach to environmental problems, therefore, "achieves the twin goal of reduced degradation of the environment and increased conservation of natural resources."[7]

Awareness Efforts Made

It's been encouraging to take note of successful applications of this approach and the increasing notice it has received. Nevertheless, it generally has not had all the recognition it should have from governments or the general public. Strenuous efforts are being made to continue increasing awareness and usage of the concept, but, all too often, the emphasis continues to be placed on pollution removal, which consists of a facility to remove pollutants before discharge to the environment. Use of removal technology — not always the most environmentally efficient method — has been forced by legislative requirements, or by short-term deadlines of recent environmental legislation.

Indications are, however, that society will avoid the trap of thinking that tomorrow's technology will be the same as today's. Reality demands that solutions to our present and future environmental problems will come from new and better technology, based on conservation-oriented systems, or the pollution-prevention approach.

The seminar of the United Nations Economic Commission for Europe dealt with the subject of low- or non-pollution technology, and concluded on a note of hope: "The question today is whether technology can solve those environmental problems which technology has helped to cause. There is widespread belief that this question can be answered positively." This is one of the reasons why this report has been prepared.

Chapter Two

Perspective On Industrial Pollution Problems

The total pollution problem is a mosaic of which industrial pollution is only one of the pieces. Others include the discharge from municipal and non-point sources, such as runoff from agricultural land, and natural pollution such as hydrocarbons from forests, and particulate from salty ocean spray.

Effective environmental management requires considering the mosaic as a whole and not the pieces individually; only then does an image appear from which to draw valid conclusions and plan realistically.

This is not, however, the approach originally taken by developed nations where air-, water- and solid-waste pollution first were regarded primarily as unrelated problems rather than fragments of the whole. "A hodge-podge of law evolved as [these] problems were dealt with individually," according to one environmental scientist.[8] This confusion was seen as occurring because many environmental laws were conceived hypothetically and resulted in regulations which emphasized the specifics of technology.

Many environmental activities have focused on pollution from industrial sources, because, in many cases, they are easier to identify and control than pollution from municipal and other sources. Industry's view is that governments could achieve better environmental results by stressing adequate treatment of municipal and all other non-point sources of pollution before requiring very refined and expensive control of industrial sources.

A context for comparing municipal and certain types of conventional industrial pollution sources was indicated in a study by the United States Council on Environmental Quality. In one recent year, the council reported, discharges from U.S. municipal and non-point sources to the nation's streams totaled 59.6 billion pounds of biological oxygen demand (BOD) and 3.703 trillion pounds of total suspended solids (TSS). By comparison, industry discharged only 8 percent of the combined municipal and non-point pounds of BOD, and only 3 percent of their total pounds of TSS.

Abatement Priorities Recommended

In the wastewater area, it seems to be especially productive for developing countries to establish an environmental infrastructure which concentrates on abatement procedures in this order:

1. Primary and then secondary treatment of conventional pollutants such as biological and chemical oxygen demand and suspended solids (BOD, COD and TSS) in municipal wastewater.

2. Primary and then secondary treatment of conventional pollutants from industrial sources which discharge directly into the water course.

3. Treatment of industrial toxic wastes. This step can be implemented simultaneously with treatment of municipal wastes. If low- and non-pollution concepts are followed, this step can be postponed, or even eliminated, in some instances.

4. Control of non-point pollution. This is difficult, because all discharge sources cannot be easily identified or controlled. Soil erosion and agricultural run-off are the major source of non-point pollution.

It is costly in terms of money, manpower and natural resources to build and operate conventional pollution-control facilities to remove pollution that already has been created.

In one year alone, for example, 146 chemical companies in North America consumed the energy equivalent of 61 trillion Btu's for pollution-control activities. This was 7.3 percent of the total energy requirement of those companies, and enough energy to supply a year's heat and electricity for 300,000 typical homes in a climate as severe as that of Chicago.

These same companies — 130 in the United States and 16 in Canada — also estimated that their pollution-control spending for two recent years would be 8.1 percent of total capital investment. Furthermore, this rate of investment was double that of the decade 1961-1972.[9]

Pollution Control Costs

Representative figures are available for the U.S. economy. The Council for Environment Quality estimates that the total U.S. expenditure for pollution control in 1979 was $55.9 billion, which was more than 2 percent of Gross National Product and more than 14 percent of gross private investment. Of this amount, the industrial sector alone spent $13 billion for just air- and water-pollution control — the equivalent of $170 for every household in the country. In the decade through 1988, this spending was forecast at $167.5 billion in constant (1979) dollars, or about $1,900 per household.[10]

The Conference Board, a U.S. business organization, estimated that water-pollution-control costs relating to value of output would escalate as a percentage of value added. These percentages were projected:[11]

Industry	**1972**	**1977**	**1983**	**1985**
Pulp, paper and paperboard mills	2.2	5.8	6.5	32.3
Alkalies and chlorine	0.8	1.2	2.1	3.5
Industrial organic chemicals	0.6	4.8	7.2	n.a.*
Petroleum refining	0.7	1.9	4.9	5.6
Blast furnaces and steel mills	2.1	6.1	11.9	n.a.

**Not available*

The 1972 figures are baseline estimates of abatement costs if the 1972 Clean Water Act had not been enacted. The figures for 1977 and 1983 are interim projections as compliance moves toward the goal of zero discharge in 1985. They are based on projections of "what would occur with respect to output, water use and water-pollution-control costs, given the set of arbitrary effluent abatement requirements examined."[12]

Projected annual abatement costs rise faster in the compliance case than in the baseline case, because effluent standards under the 1972 law escalate more rapidly than they would have in the absence of this legislation.

At least some of the higher costs are likely to be passed along to the customers of an industry, who are expected to purchase somewhat smaller quantities of the industries' products. The relatively low, 3.5 percent, figure for alkalies and chlorine "masks the fact that zero discharge requirements will push soda ash costs so high that the manufacture of soda ash will cease to be economically viable."[13]

Statistics such as these indicate that expenditures for pollution-control equipment and operations in some cases can become a significant drain on the total money available to an industry or national economy for real expansion.

Delay Solves Nothing

Cost problems won't be solved by delaying installation of pollution controls until a certain stage of industrial development has been achieved. If anything, the cost of retrofit controls becomes an added drain on funding for the next growth increment.

On the other hand, implementation of low- or non-pollution technology has the inverse effect of releasing money for industrial expansion or other societal uses. Opportunities also are created for using recycled wastes, setting up waste-savings systems, internal recycling, improved yields and the application of energy saving techniques.

As an example, waste-saving techniques appear to offer special advantages. In milk pasteurizing, for instance, a countercurrent exchange system can recover from 80 to 95 percent of process heat for reuse.

Using recycled wastes as raw materials also can save a considerable amount of energy. For example, to make a ton of steel from ore requires 23 million Btu of energy. Through the recycling of scrap, the per-ton cost of energy drops to 8 million Btu. The decrease is even more dramatic for aluminum — from 218 million Btu to 9 million Btu. Making a ton of paper from recycled waste has a lesser, but still significant impact on energy cost, reducing it from 28 million Btu to 21 million Btu.[14]

The resource-conservation aspects of low- or non-pollution technology also include the use of residues as natural resources. The concept of pollution as a resource at the wrong place or in the wrong function can be illustrated by a simple equation:

Pollutants (waste materials) + Knowledge (technology) = Potential Resources

An example is the creation of nylon from the waste byproducts of petroleum some years ago.

This concept also considers factors such as the stream's natural reaeration capacity for self-purification. Calculations based on data compiled by the U.S. Geological Survey about 11 major rivers indicated that they generated about 1 million tons of oxygen daily to clean themselves. To provide the same amount of oxygen by manmade, mechanical aeriation would require about 350 million barrels of crude oil, or 90 million tons of coal. Those figures represent the equivalent of 10 percent and 15 percent respectively of U.S. annual production of oil and coal. Burning the coal also would create 1 million tons of fly ash, 1 million tons of nitrogen oxides and 500,000 tons of sulfur dioxide.[15] This reaeration capacity is a natural resource which should be fully utilized.

Impact Is Widespread

Low- or non-pollution technology has an impact which extends beyond the first generation of industrial pollution — that which is created in the manufacturing process. By reducing or eliminating the need for controls, it reduces or eliminates the creation of second- or third-generation pollution.

Second-generation pollution is the residue generated from pollution-control facilities. Third-generation pollution is that which is created at a distant place where energy and materials are manufactured, with which to build, fuel and operate a pollution-control facility. These subsequent-generation pollutants often are overlooked when the characteristics of a pollution problem are determined.

Low- and non-pollution technology has micro- and macro-economic aspects which must be considered in plans for this type of effort. At a conference on pollution prevention, various nations of the Council for Mutual Economic Assistance (CMEA) defined micro aspects as pertaining to individual facilities or branches of industry, and macro aspects as involving the economy as a whole. It was pointed out that a positive macro aspect could have a negative micro impact, and vice versa.[16] The CMEA nations proposed three criteria for evaluating the economics of the system:

1. Study social losses caused by failure to comply with low- or non-waste production and consumption principles.
2. Compare costs, benefits and effectiveness of wider applications of low- or non-waste production and consumption.
3. Define possible inducements (incentives) if economic methods are to be used to raise the level of low- or non-waste technology among various economic units.

How to establish a process to implement low- or non-waste technology is suggested in a report from the Federal Republic of Germany.[17]

The report urged governments to reexamine their environmental administrations to eliminate potential or actual roadblocks raised to implementation of this technology. Obstacles can be overcome, however, as evidenced by the experience of some international companies which have sought to implement low- or non-pollution technology programs. The goal has been to reduce pollution and pollution controls to the absolute practical minimum through the use of innovative technologies. Progress has been made, due in part to a continuous program of information and encouragement. Efforts to advance these programs are focused on employees in manufacturing, engineering, and research and development who are responsible for product and manufacturing-process formulations.[18] A formal procedure exists to provide personal recognition for technical contributions.

To accomplish the objectives of low- and non-pollution technology requires revising "certain parts of our environmental laws, in order to eliminate now mandatory wasteful practices, and unrealistic and costly investments."[19] While this comment pertained specifically to the U.S. situation, the applications to technology planning and development are universal, and generally pertinent to the developing nations as well.

Innovative Approaches Emphasized

Thus, more emphasis is being urged to develop process changes, product innovations, recycling — for the demonstration and installation of systems that can achieve "zero discharge," and that would provide savings in materials, energy and cost. Changeover to a low- or non-waste pollution approach can be costly in many cases, and the resistance to change may be great; however, the potential for long-run cost savings and improved environmental management make the effort worthwhile.

Chapter Three

Concepts and Principles of Low- and Non-Pollution Technology

Production for development is the lifeline of society, and low- or non-pollution technology can be applied at each link in the chain, which includes:[20]

1. Production of raw materials.
2. Transportation of raw materials.
3. Manufacture of finished and semi-finished products.
4. Distribution of products, including transportation, storage and sale.
5. Disposal and possible recycling of used products.

The concept also can be made to apply at various levels of manufacturing and other business activity:

A. Conception of product or output.

B. Design of manufacturing.

C. Design of residuals, and reuse of products.

D. Design of a central waste-handling facility to produce new resources from old residues.

E. Design of the system as a whole, including how to avoid waste "before a process begins rather than handling waste effectively after it has been produced."

Along the chain and among the links of the production lifeline, twin goals remain constant: reduced degradation of the environment and increased conservation of natural resources. Low- and non-pollution technology provides a technological option which can be used as a norm for measuring the final degree of efficiency. This takes into account human needs, which are the reason for technological development." The low- and non-pollution concept is intended to encourage production procedures under which, in comparison with other methods, "less or less-dangerous production waste arises; raw materials and energy are used more economically, and products are manufactured which, in their use and on disposal, produce less pollution."

'Recovery' Opportunities Abound

An opportunity exists for using resource recovery in the process industries, including electroplating and metal and plastics finishing. These industries have a major problem in determining what to do with waste products, particularly fluids. They also have a choice between destroying the contaminants and toxic elements in the waste, and recovering these materials for reuse. According to a report by two industry experts, however, recovery seldom has been the first approach, because, "industrial waste frequently takes several forms, and available recovery processes are usually limited to particular materials, to certain processes or to steps within the process."[21]

The usual procedure has been to build disposal systems in which waste is pooled and treated, and the resulting sludge is discarded. "Once these systems were installed, often at considerable expense," the report said, "there was understandable reluctance to consider further investment in recovery systems."

The problem was that disposal systems only convert a water-polution problem into a solid-waste (sludge) problem. "The net result is that possibilities of eventual surface-water contamination is not really eliminated, and disposal becomes more complicated." The destruct approach also is more costly in the long run, the report said, because the expense of treatment and disposal is added to the cost of recoverable chemicals lost in the process.

A number of new factors, however, indicate that resource recovery makes sense, even for manufacturing facilities which have invested in expensive destruct systems. These factors include improved recovery equipment; smaller and more affordable recovery systems and broader financial incentives from government agencies.

According to a report by the International Labour Organization (ILO), resource recovery is particularly adaptable for "multiple use, multiple product formation and internal transfer of wastes emerging from one sector to become raw material or energy inputs into another."[22]

Several examples are offered by the ILO:

In the Philippines, a copper smelter has been integrated with a plant producing sulfuric acid and fertilizer. The companion plant utilizes about 98 percent of the smelter's sulfur discharge and also is powered largely by heat produced by burning the pyrites.

In Belize, citrus factories supply the country's total need for high-protein animal feed by fermenting fruit waste to produce single-cell protein. A similar operation in Malaysia operates on the highly polluting effluent of the palm-oil industry.

In India, more than 20,000 gas plants are installed every year which convert animal and plant wastes into methane gas for cooking and lighting and produce a residue of rich manure fertilizer.

In the People's Republic of China, residue of production generally is considered a byproduct and not a waste. Even the bauxite residue from alumina production is converted into building materials and aggregate, according to the ILO report.

Other examples of manufacturing integration include:

Integrated Systems	**Wastes Avoided**
Garbage Disposal, to Fuel Production, to Metal Recovery	Land, Resources
Paper-Alcohol-Protein	Water Pollution
Electricity-Insulating Bricks	Solid Wastes
Domestic Water-Industrial Water-Pollutant Recovery	Water Pollutants, Resources
Steel-Ceramics	Solid Wastes
Mining-Building Material (bricks, cement, aggregate)	Solid Wastes

Environmentally Compatible Strategies

A general recommendation has been made by the United Nations Environment Programme (UNEP) and the Food and Agricultural Organization (FAO) that "each country and industry should establish definite, feasible residue utilization strategies and priorities for residue utilization that reflect realistic social, economic and technical goals."[23] "This strategy," they have reported, "must be compatible with environmentally sound decisions that reflect existing physical, human and other resources. Such strategies and priorities should take full account of the interrelated policy questions of land use, energy and transportation as well as the various socio-economic, ecological and environmental considerations."

The foregoing led UNEP/FAO to conclude that establishing this approach "will call for coordination among responsible authorities . . . and may require the establishment of suitable mechanisms for this purpose. Authorities should ensure that appropriate controls and regulations are based on sound scientific data, and they are enforceable. Care also should be taken not to create non-tariff trade barriers through unjustified restrictions.

One UNEP/FAO recommendation may be of primary importance for developing nations. It suggests that "in each country and its industrial operations, a major programme should be initiated to identify, control and reduce the major losses in food materials, i.e., generation of residues, which occur in food processing between harvest and consumption." This concept also is applicable to industrial operations, as will be described later on in this document. It is an important concept to one environmental scientist who believes that "the very sustainability of dignified life on this planet earth must depend on reestablishing a non-waste society, a non-waste economy, a non-waste technology and, above all, a non-waste value system." This includes a technology based on "the total system of raw material supply, production, consumption, disposal and recycling, viewed in an integrated and systematic fashion so that no waste occurs."[24]

This scientist calls for systems engineering to develop "integrated units which will produce a wide range of products without waste." To complete the concept, he adds the selection of products which contribute most to human needs and "finally, research on renewable resources of both energy and raw materials."[25]

Chapter Four

Managing Transition to Conservation Technology

"A creative economy is the fuel of magnificence," the poet Emerson proclaimed, praising the spare use of nature's bounty. This maxim can apply as well to that system of production, distribution and consumption which we call an economy, and which provides the material means of satisfying human desires. The creative manifestation of this economy lies in the application of low- and non-pollution technology.

A transition from today's technology into a state of low- or non-pollution technology, however, cannot be made unless political, economic and technical forces all are taken into proper account. "The transition . . . will not just be brought to us by anonymous economic forces. It must be made an explicit goal of politics and an issue of primary governmental concern."[26]

The transition often is not profitable, and laws and executive practice have evolved in periods when low- or non-pollution technology was unknown or unimportant, and it often has been incompatible with traditional patterns.

The urgent need for transitions often is linked to sudden crises, such as the environment, oil, food-supply or social change. This strongly implies the need to plan in advance of crisis. If new technology can provide a solution, it comes about too late if research and development do not start long before the crisis is upon us.

One problem is that nobody can forecast the pattern of consumption, the acceptable price level and the political preferences 50 or even 30 years from now, but yet this is the technologically necessary time horizon. But it also is clear that if we leave these problems to the future, suddenly there would be too many to be solved at all.

Low- and non-pollution philosophy therefore becomes one tine of a technological tuning fork of which engineering design is the other. In theoretical aspect and practical application, they resonate in harmony.

One suggested implementation approach is to build the philosophy of low- and non-pollution technology into the engineering design.

In proposing this, Twente University of Technology in The Netherlands defines the difference between being philosophically and technically specific.[27] Engineers can employ the conserver philosophy at each stage of product or process design, according to their own involvement. However, low- or non-pollution technology per se is such a broad field that there can be no master list of technical steps to follow. Furthermore, its implementation demands at present measures different from those that will be necessary. Most products, devices, machines, and the like, to be used in the future still have to be designed, and this places the designer in a key position. For this reason, it is of very great importance for the implementation of low- and non-pollution technology in any society that a large number of well-motivated engineers, scientists and other technical personnel propagate the concept.

In this approach, three interrelated problems are involved, namely the limited amount of raw materials available; the menace of energy shortage, and the rapid pollution of the environment.

It was proposed that the causes of these problems be analyzed to find solutions. Three approaches were suggested:

1. Positioning — finding new supplies of natural resources. The effect is short-term.
2. Curing — recycling of present waste materials. This is a mid-term solution that has some effect on extending supplies.
3. Preventing — avoiding the problem in the first place. This is a long-term solution.

Positioning and curing are offered as remedies to be applied when crisis threatens. However, action cannot be delayed in the effort to find an alternative to rapid depletion of energy and raw materials.

The prevention approach is preferred, because it takes all the future impacts into account. Prevention provides that long-term solution which can be achieved only by insuring that problems in relation to materials, energy and environment do not arise.

Options For Action

In this matter, governments have two options for action. They can help bridge the gap between concept and technical reality, or unintentionally throw up obstacles to this progress.

Roadblocks to pollution prevention have existed, as described elsewhere in this document, because "many laws and their interpretation are pointed toward removal technology alone."[28] They specify the means of pollution abatement while ignoring or not considering the overall results.

That situation appears to be changing in some developed nations, however, as present environmental approaches are found to be inadequate or obsolete, and governments and industries therefore reassess their attitudes and positions.

By their size and central nature, governments have many opportunities and means to inform and educate the industrial sector, public and themselves about low- and non-waste technology.

Examples include "Non-Waste Technology and Production," an international seminar conducted by the United Nations Economic Commission for Europe,[29] and four regional conferences sponsored by the United States Environmental Protection Agency and Commerce Department.[30]

The United Nations seminar was held in Paris in 1976 and was attended by representatives of more than 30 countries with various types of central and free-market economies. It was, perhaps, the first time an international convocation studied low- or non-waste technology.[31]

The four EPA/Commerce Department conferences in the U.S.A. in 1977 were among the first events in that country to focus widespread attention on pollution-prevention accomplishments and possibilities. They were held in Chicago, Illinois; Boston, Massachusetts; Dallas, Texas, and San Francisco, California, and provided broad national exposure for the concept.

It was at the San Francisco conference, "Pollution Imagineering Pays," where William Ruckelshaus, the U.S. EPA's first administrator and now a businessman, said that industry and government were entering a new, third stage in their relationship which involves "accommodation of environmental, social and economic goals."[32]

This "third stage," Ruckelshaus said, reflected a growing understanding that "everything is connected to everything else," including the environment, consumption of energy and other resources, and the economy.

Stage Three, he said, was a natural progression from Stage One, "the Earth Day awareness that we were fouling our nest," and Stage Two, "the political response demanded and received."

The magnitude of governmental interest in low- and non-pollution technology was indicated at the Dallas conference. C.L. Halsam, general counsel of the U.S. Commerce Department, commented: ". . . it is becoming apparent that issues in these [environmental] areas must be addressed not in isolation but as elements of a larger, single issue, by those responsible for developing regulations as well as by those responsible for complying with them."[33]

Alternatives and Innovation

The pollution-prevention and resource-recovery approaches demand "that industry and government take the initiative," Halsam said. Industry must seek technical alternatives to end-of-pipe pollution controls, and "government must insure that the statutory and regulatory framework does not stifle innovation. Indeed, it must encourage such innovation through reasonable and flexible tax and pollution-control laws and regulations."

Some policy options for government to employ have been suggested.[34] They include:

1. Support of basic research in universities and research institutes.
2. Creation and support of national laboratories.
3. Deductibility of research and development expenditures for computing income taxes at some multiple of the actual outlay.
4. Taking research and development expenditures as a tax credit rather than a deduction as a business expense.
5. Diversion of more federal research and development to industry.
6. Funding of demonstration plants.

Additional proposals have included:

7. Using of management-by-objective principles in writing environmental laws and regulations, which specify results and allow great technical latitude in achieving them.
8. Involving the private sector, including academia, industry and individuals, in the environmental decision-making process.
9. Managing the environment, not just protecting it. An example is using the self-purification capacity of the environment when calculating allowable discharges into water courses.
10. Encouraging regulatory innovation such as discharge limits for a total facility rather than for individual sources within the facility. In the U.S.A., this is

called "the bubble concept," and it has been applied to particulate and hydrocarbon-discharge requirements. Emphasis is on total quantity, not concentration.

11. Standardizing definitions and parameters of environmental terms and concept such as "clean" and best-practical and best-available technology.

The United Nations Economic Commission for Europe has given its official endorsement to the concept of low- and non-pollution technology, which the ECE has categorized as a necessary approach to environmental problems.

The ECE has been involved actively in this field since 1973, and made it a subject of importance at the group's ministerial meeting in May 1979. At this session, the ministers acted upon a thorough background document which spelled out in detail "Guidelines for the Compilation of a Compendium on Low- and Non-Waste Technology."[35]

A four-year project has been undertaken, based on this document, which consists of two aspects:

— Sub-project A, which is concerned with the compilation and dissemination of available, current knowledge regarding industrial low- and non-waste technology within member nations of the ECE.

— Sub-project B, which deals with development of methods and criteria for assessing and analyzing industrial technologies, and testing these methods on specific technologies identified in sub-project A.

Two case studies illustrate how successfully the transition can be made from conserver philosophy into practical application. In the first, low- or non-pollution ideals have been incorporated into a polluter-pays program in France. In the second, an international company has set up a transnational program to encourage widespread use of conservation technology by its scientists and engineers.

In France, the polluter-pays and pollution-prevention approaches have been combined successfully. The general rule is "to make the perpetrator of the pollution pay for the costs involved with it."[36] This is regarded as the most equitable way of achieving compliance with desired environmental standards. However, incentives and encouragement are provided to guide the polluter to adopt low- or non-pollution technology wherever possible as "the means with the best performance and the least cost to meet with the objectives assigned him by regulations."

This effort has been carried out by the Agences de Bassin (the Basin Agencies), six hydrographic districts created by law in 1964 to establish policy for water-resources management. The Agences Financieres de Bassin (Basin Financial Agencies) are empowered to collect fees from industries which pollute waterways, and to grant financial aid to those which invest to reduce their pollution of water.

Some of these agencies have provided greater incentives for pollution reduction than for pollution controls. For example, financial grants for waste-treatment facilities tend to be influenced by how well a company tries to install low- or non-pollution production methods.

Conservation Projects Supported

Beyond this, scientific committees of the Ministere de la Qualite de la Vie (Quality of Life Ministry) provide research funds for projects which comply with conserver objectives and subjects. These committees are concerned with air and water quality and solid-waste disposal. They have funded a variety of projects, including dry peeling of potatoes, steam scalding of poultry and blanching of foodstuffs. In addition, any new procedure which offers exceptional promise for protecting the natural environment can receive a subsidy from the Fond Interministeriel d'Action pour la Nature et de l'Environnement (Interministerial Action Committee for Nature and the Environment).

In the six hydrographic basins, maximum discharge limits are established for a factory according to its activity and the desired level of environmental quality. These limits correspond to the best pollution controls presently available, or manufacturing methods free of wastes when such methods exist. It is significant that the selection of equipment is still left to the industrial concern so as to leave the field open to innovation. France also has a sector policy administered in each of its provinces and based on instructions from the Ministere de la Qualite de la Vie.

Working with industry representatives, provincial prefects conduct case studies of establishments in each of the most polluting industrial sectors. These studies provide the basis for establishing emission standards which are "precise indicators of the pollution levels which the best pollution-control techniques presently available make it possible to achieve," unless the industrial sector can come up with alternatives which provides equally effective — or better — sollutions.

When an environmental objective can be achieved only by using a low- or non-pollution production method, this is then indicated in the instructions to the prefects by the Ministere de la Qualite de la Vie. Examples include requiring sugar factories to dry clarified foams and potato-starch factories to recover proteins in wastewater. The door is left open to environmental-technology innovation. Thus, most often, it is only the goal which is specified.

Pollution Prevention Pays

In the industrial sector, some companies have implemented programs to encourage low- and non-waste technical innovations. A specific example is "Pollution Prevention Pays." The 3P Program, as it also is known, was introduced by the 3M Company[37] in 1975, to help reduce the amount of resources, manpower and money necessary to comply with environmental laws and regulations.

The program first was implemented in the company's United States Operations, where its largest concentration of technical and manufacturing activity is found. Subsidiary companies in other countries then adopted the program to meet their own requirements.

The "Pollution Prevention Pays" concept evolved as compliance with environmental laws and regulations became more costly and complex. It had become apparent that the only practical way to hold down environmental costs was by eliminating or reducing pollution at the source. This approach had been used previously, but not on an organized, worldwide basis within one organization.

The 3P Program materialized as a comprehensive effort to encourage pollution-prevention activities by all manufacturing, laboratory and engineering technical employees. They were encouraged to seek results through:

1. Product reformulation.
2. Process modification.
3. Equipment redesign.
4. Recovery of waste materials for reuse.

The name "Pollution Prevention Pays" was selected after some debate whether the word "pays" should be associated with environmental activity — regarded as a societal obligation as well as a regulatory requirement. However, four valid payoffs were defined: improved environment; conserved resources; improved technologies; and reduced costs. "Therefore, it was concluded, payoff not only should be equated with pollution prevention but was an essential motivating factor."[38]

Innovators Are Recognized

A program of personal, professional recognition was established to focus attention on pollution-prevention innovators. A "Pollution Prevention Pays" coordinating committee also was established in every country where the 3P concept was appropriate to 3M technical and manufacturing activity.

Each coordinating committee has members which represent the local company's engineering, manufacturing and laboratory organizations. They decide who should be credited with and professionally recognized for innovation.

Four criteria are used to judge a project:

1. It must eliminate or reduce a pollutant that is a problem or a potential problem.
2. It should exhibit improved use of energy, raw materials or other resources.
3. It should incorporate a technical accomplishment, innovative approach or unique design.
4. The accomplishment must have some monetary benefit.

Success of the program is indicated by its results over the first six years. Recognition was provided to 545 projects in 20 countries. These produced a total saving of $97 million.[39] These savings include $76.5 million from U.S. Operations and $20.5 million from International Operations.

In the U.S., 3P savings included: $19 million for pollution-control equipment and facilities which were delayed or eliminated; $42.3 million for pollution-control operating costs; $4.2 million for energy savings not included in operating costs, and $11 million for sales retained of products which otherwise might be taken off the market as environmentally unacceptable.

Each year, the 3P Program prevents the creation of these pollutants:[40]

	U.S.	**International**
Air Pollutants	123,000 tons	4,000 tons
Water Pollutants	4,000 tons	150 tons
Wastewater	900 million gal.	279 million gal.
Sludge/Solid Waste	12,000 tons	1,500 tons

The program also produces an estimated annual energy conservation of 1.2 trillion Btu, or the equivalent of 228,000 barrels of petroleum.

Projects have ranged from improved control of process coating weight at Gorseinon, Wales, and recycling of wastewater at Hilden, Federal Republic of Germany, to a variety of combustion-control and heat-recovery processes in Japan. Among the larger projects was a process change in the United States that solved an odor problem, and eliminated the need for a $1 million thermal oxidizer and $50,000 annually to fuel and operate the oxidizer.

It took 3M Company from 1975 through 1978 to refine the "Pollution Prevention Pays" concept and introduce the program throughout its worldwide operations. This complicated task of introduction was undertaken by the company's Environmental Engineering and Pollution Control organization. It conducted a vast series of technical-group meetings which were supported by audio-visual devices, and an extensive employee-awareness program.

Effort was applied first where potential results were the greatest — for example, in areas where hydrocarbon emissions could be reduced through process change. Then, priorities were set and followed to spread the program.

Beginning in 1979, the "Pollution Prevention Pays" Program was considered as mature. The 3M environmental group, however, continued its extensive informational and recognition campaign. This was done to sustain the momentum gained during the program's first four years. Emphasis was shifted, however, from announcement to reinforcement of the concept. This stage will be continued indefinitely, "until the conserver approach becomes a way of technical life."[41]

Chapter Five

Cost/Benefit Evaluation

Cost and Benefit are point and counterpoint which must be offset to determine net social gain from environmental activities. The problem is that net social gain is a moving target as society's priorities change and become elusive to define let alone measure.

Establishing these criteria is more difficult than might appear at first. Costs are simple to identify and measure, but benefits are difficult. The situation is complicated by the fact that those who pay the costs (industry, for example) are not necessarily the same as those who benefit (society). This explains at least in part why cost/benefit evaluation remains somewhat a tentative procedure.

With industry profits and employment down in many countries, strong political pressures have led to changes in national priorities. Thus, promotion of energy-saving measures, reduction of unemployment, control of inflation and many other concerns have become areas of top priority.[42]

Other examples include approval by the United States of the Alaskan Oil Pipeline as the country felt the first pangs of energy hunger.

These changing priorities indicate a definite need to establish a means for evaluating environmental activities in context with the total demands of an economy or industry for manpower, energy, materials and money. A base level from which to begin has been suggested: There is no room for compromise about environmental activities which relate to protection of public health, but definite cost/benefit criteria should be established for benefits going beyond health protection.[43]

It was further suggested that, given an alternative, the resource-conservation approach should be taken to prevent pollution at the source, before clean-up problems are created.

Costs and Benefits Balanced

Listing changes in cost-benefit ratios for "a given system, or product, or societal action" is extremely difficult. As one environmental scientist describes it, "state-of-the-art in predicting long-range effects in complex, independent, poorly defined systems — i.e., the real world — is really quite poor, and what may be perceived as a minor 'benefit' can become highly significant with time."[44]

This scientist warns that "the return on investment reaches a maximum in accordance with the marginal return principle." Estimates of benefit and cost are essential to a rational approach to complex decision making. The digital computer provides us with a tool for handling such complex systems, but the results are no better than the input data or the basic model utilized.

In a report, the United Nations Environment Programme agrees that it is necessary for society "to further sharpen the analytical tools already being applied to practical work. Especially in case of environmental or ecological issues, problems of uncertainty with respect to long-range consequences of today's decisions and actions play an important role.

"It is essential to improve the data base for future decision making with regard to environmental quality management. Detailed empirical investigation at the plant and industry levels is a useful starting point for such an exercise."

At a seminar, a materials-balance approach was suggested as one means of easily identifying "the benefits of avoiding waste and the costs of reducing waste to an optimal level."[45] A list of positive and negative factors was suggested as a basis for weighing against each other to determine costs versus benefits.

Preservation and Protection

Among the benefit points were preservation of the natural-resource base and protection of assimilative capacity of the environment to absorb those discharges which continue to be released.

Cost counterpoints centered around reductions or changes to the Gross National Product (GNP), lost jobs and increased costs and prices.

When comparisons were made, the optimal level was likely not to be zero, as the term "non-waste technology" implies. Instead, it often was found to involve trading off the benefits from avoiding waste with the costs of avoiding waste.

As was noted, those who pay and those who benefit are not necessarily the same. Therefore, the most important part of analysis is to decide for whom the analysis is being performed, or, which benefits and costs matter. Analyses are better when they are specific rather than general, because in practice, we are more likely to settle for cost minimization or cost effectiveness in achieving a particular target or goal.

A means to evaluate the "particular target or goal" can be devised from a procedure developed by the Conference Board in the United States to measure the economic impact of water-pollution-control legislation.[46] The procedure is based on compliance with the 1972 Water Pollution Control Act in the U.S.A. and its various amendments and compliance dates. There are four steps to the procedure:

1. Historical patterns of water intake, use, discharge and treatment are studied in terms of both total and per-unit physical output. Movements of these measures are explained in terms of changes in technology, production processes, output and input mix.

2. A baseline projection is prepared on the assumption that the 1972 act had not been passed. This projection, based on historical industry perspectives, attempts to indicate how environmental events would have transpired without the law.

3. A compliance case is analyzed to determine how the industry will meet with original and subsequent requirements of the law and to estimate costs associated with compliance.

4. The final step is to compare the baseline and compliance projections. The amount by which net capital expenditures in the compliance case exceed those in the baseline case constitute an aspect of economic impact.

The Conference Board procedure was developed as part of a study of five industries.[47] Quite unsurprisingly, the board discovered the "basic economic fact that establishments seek the least costly method of achieving abatement."

The study also found that the least costly method of reducing water pollution was by the introduction of new production equipment and, by inference, development of new processes. New production facilities are less polluting than old equipment; and end-of-pipe treatment of wastewater is usually more costly than are changes in capital equipment. Direct and indirect effects were defined. Direct effects include impact on an industry's prices and profits and the competition for capital outlays between environmental requirements and other business needs and demands. Indirect effects were defined as "those that are transmitted to (and from) economic units other than the establishment or industry under study. These include higher prices which cause shifts in demand and inability to compete with foreign producers in domestic and foreign markets. They also include higher interest rates and diversion of funds due to bidding for capital. Layoffs and worsened profit prospects were other impacts described as outside the scope of the study.

Empirical Approach Succeeds

In France, pollution-free integrated technologies "often find their basis in an act of faith on the part of their promoters." These ventures are said to "owe their successes to a highly empirical approach which is worked out progressively with the development of the project."[48] These involve primarily a comparison of variables of industrial projects making use of competitive processes "but which are perfectly defined and which have been developed for a long time." France, like most countries, has three choices when confronted with a pollution problem:

1. Do nothing and continue to pay pollution fees. This situation is temporary; the fee is likely to increase, and government pressure will be felt to reduce pollution.
2. Reduce the pollution by treating effluents. This involves capital and operating costs for abatement.
3. Investigate how to eliminate the pollution through process change, to recycle or recover the pollutant, or upgrade it to profitable uses. These technologies are called "techniques propres."

For economic analysis, the first scenario is the status quo and the subsequent two scenarios represent variables that are appropriate to evaluate. "Analysis then consists of a separate evaluation of the additional costs and benefits which are connected with the selection of one or the other system." Other factors to be considered include definition of the cost criteria and evaluation of "the various viewpoints which can be taken into account" — the community, government and industry. The total net benefit to the community is expressed by the algebraic sum of the benefits and costs for the different economic agents, a sum obtained by bringing together the two lists of criteria.

Social and Financial Costs

Evaluation from the separate viewpoints of industry and the community make it possible to determine the differences that could exist between social and financial costs "and thus to gain insight into guidelines for a policy to be instituted by the government agencies concerned." If the analysis is completely carried out, it should provide answers to these questions:

1. Is the net benefit to the community from low- or non-pollution technology greater than the net benefit from classical treatment methods?

2. Does this technology lead to a net benefit to industry? If so, what is this benefit?

3. Can the net benefit to industry, if it exists, be expressed in money terms?

An example is provided at the Strasbourg plant of a private company making yeast where the concentration of unfermented yeast in solution is reclaimed for use in fertilizers and cattle feed.

The method of recovery provides an almost complete reduction in pollution. For 1 ton of yeast, the biological oxygen demand (BOD) fell from 127 kg. to less than 6 kg., and the chemical oxygen demand (COD) from 174 kg. to less than 10 kg. In addition, recycling reduced water consumption by 70 percent.

A biological treatment station reducing pollution by the same 97 percent would have required twice the investment. The integrated installation cost 5.2 million francs, compared with an estimated 10.8 million francs for biological treatment. Operating costs were 680,000 francs for the integrated facility, compared with an estimated 1.08 million francs for a treatment plant.

The Strasbourg facility also had protein-derivative sales of 786,000 francs and potassium extract sales of 247,500 francs. Total gain from the operation, excluding amortization, was given as 1.235 million francs. This includes an operating balance of 155,500 francs plus the savings of 1.08 million francs it would have cost to operate the treatment facility.

The Economic Commission for Europe "Guidelines for the Compilation of a Compendium of Low- and Non-Waste Technology" is one of many readily available, published approaches to evaluating costs versus benefits.[49]

The Economic Commission for Europe "Guidelines for the Compilation of a Compendium of Low- and Non-Waste Technology" is one of many readily available, published approaches to evaluating costs versus benefits.[49]

Chapter Six

Examples of Low- or Non-Pollution Technology

From strip mines to laboratories, the concept of low- and non-pollution technology is being translated from abstraction into reality. Several examples are offered to show what is being accomplished.

Mineral Raw Materials

As civilization matures, the demand rises for mineral raw materials, including more diversified chemical elements which are rarer in appearance and lower in natural concentration.

This has led to an increase in the amount of minerals exploited and, consequently, to a disproportionate increase in the amount of tailings after useful materials have been extracted.

Examples include non-ferrous metal ores, radioactive elements and rare-earth elements, the primary concentrations of which are about one-tenth of 1 percent.

In Poland, projections are that wastes from mineral use will form a mountainous 7 billion tons by 1990, not including strip-mine overburden.[50] That country long has realized, however, "It's a false opinion that both mining and technological wastes are entirely useless. When they are not consumed by the industrial branch which produces them, they still may be used by other branches, either directly or after processing."

Since 1959, for example, the Polish-Hungarian Haldex Co., Ltd., has been established to exploit dumps of coal schist. As a result of induced technology, coal contained in the primary wastes is recovered, and secondary wastes are used in the cement and ceramics industries or as fill material.

Since 1970, the Polish Committee of Science, Higher Education and Technology, the Ministry of Mining and Power Industry and the State Mining Council have made cooperative decisions aimed at stimulating full-scale utilization of mineral resources.

Implementation follows a three-step procedure of (a) cataloguing waste raw materials; (b) analyzing possible ways of utilizing them, and (c) defining the economics involved.

The classification process includes geological mining and technical processing. It's intended to produce entire utilization of useful elements and a reduction of wastes either as post-technological tailings or secondary products of material processing.

An example is offered in the processing of polyhalites, a mineral consisting of potassium and magnesium sulphates and anhydrite. The main task is to extract polyhalites as the principal material and rock salt as the secondary one.

Primary processing produces polyhalite, rock salt or brine and anhydrite. Polyhalite than becomes the final concentrate. As such, it receives secondary processing to produce sulphate-type potassium fertilizers, potassium-magnesium fertilizers, anhydrite and lyes.

Additional processing of anhydrite and lye, either in the primary or secondary stages, produces evaporated salt, magnesium oxide, sodium and potassium lyes, magnesium sulphate and sulphuric acid as well as grain-like anhydrite for use in building binders and prefabricates. Whatever anhydrite is not consumed by the building industry may be transported to the mine for use as fill.

Wastewater Recycling

At a 3M manufacturing plant in Alabama, U.S.A., analysis of a wastewater stream showed that about 50 percent, or 1,000 gallons per minute, came from process cooling.[51]

The water required primary treatment, because it came into contact with process vapors. If the water could be recycled for reuse, a new treatment facility could be designed to handle only half the originally planned flow.

Engineers, however, were facing major problems, including heat and the unknown effects of a build-up of organics in the water. It was thought the organics might foul the cooling system and interfere with process operations.

Interest was maintained, however, because technical and cost comparisons showed that recycling would be more effective and less costly than water treatment to meet regulatory requirements for a 90 percent reduction in biological-oxygen-demand (BOD) discharge into a river.

The process was modified to operate at 90 degrees, rather than 85 degrees, which had been required previously. This eliminated the major problem of how to cool the recycled water sufficiently. A cooling tower was installed which got water temperature down below 86 degrees, well within the new operational limit. The organics proved to be no problem.

The system provides 1.4 million gallons of recycled cooling water daily which is used an average of 100 times before being discharged to the wastewater-treatment facility.

As a result of the recycling system, the wastewater-treatment plant planned for resin-making operations and other facilities was scaled down. The cost was reduced $800,000 as hydraulic capacity was reduced to 1,100 g.p.m. from a planned 2,100 g.p.m. The cooling system cost $480,000 to build, so there was a net savings of $320,000, plus some operational savings as well.

The recycling also has reduced overall flow of water through the plant, providing more available water for critical and non-contact cooling.

Similar results have been obtained elsewhere.

At a Dow Co. chlor-alkali plant in California, U.S.A., recycling[52] of wastewater has reduced consumption from 20,000 g.p.m. to 1,000 g.p.m. At another Dow plant, in Michigan, U.S.A., the company installed 28 cooling towers at a cost of $7.2 million to reuse cooling water. Improved operating efficiency and lower water costs were expected to produce a 10 percent return on investment.[53]

Alcolac, Inc., a manufacturer of specialty organic chemicals, is using a complete recycle system at a plant in Missouri, U.S.A., to obtain essentially zero discharge.[54] This involves biological oxidation, followed by filtration and activated carbon adsorption, which also helps to control odor.

Heavy metals, mainly from used catalysts, are precipitated, filtered and sold to a metals reclaimer. Organics are oxidized and filtered, so suspended solids will not plug the activated-carbon filler. Waste brine is evaporated and the salt used for highway deicing in winter.

Process cooling water is checked for contaminants, treated if any are present, and returned to a 20-acre lake. The only water not recycled is diatomite-filter backwash, which is used to irrigate grass on the plant property.

The zero-discharge approach also is being tried by the 15-ton-per-day Robertson Paper Mill, Hinsdale, New Hampshire, U.S.A., and 150-ton-day Papierfabrik Harzer paper mill at Rhumspringe, Federal Republic of Germany.[55] Both use so-called "super cells," which clarify water in 2 or 3 minutes, instead of 2 or 3 hours, as with conventional clarifiers. This fast clarification is said to eliminate odor, biofouling and temperature loss. Clarified water is adequate for meeting a paper mill's fresh-water-replacement requirements.

Estimated annual savings of such a closed system are $233,000 per year for heat, fiber and sewage charges alone for a hypothetical 200-ton-per-day paper plant.[56] At this rate, it is estimated, a "super cell" system will pay for itself in 2.2 years. The savings do not include capital conserved by eliminating the need for secondary and tertiary treatment, nor do they include charges for polluter-pays levies now being adopted in some countries, based on the amount of biological-oxygen-demand (BOD), suspended solids and wastewater.

The Great Lakes Paper Company has installed a countercurrent, closed-cycle production mill and other innovations to handle wastewater treatment at a plant at Thunder Bay, Ontario, Canada. The plant site is too small for aeration tanks and other standard external methods of treatment.[57]

The countercurrent system is designed to wash bleaching stages of the pulp with just enough water to send waste-laden effluents to a chemical recovery system. In addition, the bleaching stages use a new chlorine compound, and this has reduced the production of machinery- and pulp-damaging chlorides by 80 percent.

Another innovation is the dry barking of wood, which is used instead of conventional water barking. This has eliminated bark residue from the effluent, which has increased fiber yield and reduced operating manpower.

Capital and operating costs are lower for the closed-cycle mill than they would have been for an external primary and secondary effluent-treatment system that does not eliminate biological-oxygen-demand (BOD), color or toxicity. Total annual savings from operating expenses are expected to be about $4 million, or about half the $8 million cost of installing the closed-cycle mill in the 250,000-ton-per-day plant.

Lignite Transformation

Water supply in the German Democratic Republic is low in relation to population density; this requires the multiple-step utilization of water in large industrial plants and complexes.

One example is at a lignite transformation complex which produces and consumes 100,000 tons of coal daily. Its products are "upgraded energy carriers" (electricity, coke and gas) and also raw materials (tars, phenols and sulphur).[58].

Workers at the facility have developed a nearly closed circulation system for treating liquid- and solid-waste products and reclaiming resources from these residues.

The production cycle begins at an opencast mine which includes operating pits as well as exploited area undergoing reclamation and space for future development. Raw lignite from the opencast is distributed to a power plant and a briquetting factory. The power station produces electricity for public use and steam for the briquetting facility. Lignite briquettes are supplied to a high-pressure gassification plant and a high-temperature coke plant. Both facilities produce gas and coal-transformation products such as phenols, tars and sulphur.

An essential aspect of the multiple-step water utilization within the complex is the fact that no continuous enrichment with harmful matter occurs. Wastewater is purified in several stages and leaves the complex practically free from any harmful matter.

Multiple use of water permits the facility to meet environmental requirements by discharging clean water. It also reduces considerably the cost of fresh-water use and produces settling pond residues that are used as fuel to achieve an annual savings equivalent to 900,000 tons of raw lignite, or a 2.7 percent increase in the energy-transformation efficiency of the complex.

Metal Recovery in the Plating Industry

The climbing film evaporator (CFE) and electrolytic oxidation are two resource-recovery technologies which are helping the electroplating industry to cope with costs, raw-material supply and environmental problems.

Both technologies are employed by the Guide Division of General Motors, Inc., a supplier of plated automotive trim, to manage its chromium resources and to deal with four factors common to the plating industry:[59]

1. Costs of chromic acid have steadily increased during recent years.
2. Costs for treating chrome-plating wastes exceed the cost of purchased metal.
3. Disposal sites for hydroxide sludge from chrome plating are limited, and disposal costs are high.
4. Increased attention by environmental regulatory agencies toward toxicity of chromium makes it desirable to minimize its discharge from a process.

Like many other electroplaters, the Guide Division had been recycling stagnant rinses following the electroplating bath as a means of resource recovery. This has been a standard industry procedure.

Additional costs and complexities were incurred, however, when the firm began production of electroplated plastic parts in 1969. A climbing-film vacuum evaporator was chosen to provide more effective resource-recovery technology. The CFE system consists of an etch tank followed by four rinse tanks.

Three evaporators were installed on the plastics-preplate line, and a substantial reduction was noted in the amount of waste chromium being treated. Two electrolytic oxidation systems were used to recover chromium that remained in solution.

The capital cost of the three evaporators and two oxidation systems was $170,000. The first year's savings were 1.05 million pounds of chromic acid, or $1.18 million. Oxidation contributed an additional savings of 230,000 pounds.

Industrial Uses for Whey

For every million tons of cheese produced annually in France, about 7 million cubic meters of whey result as a byproduct with a high concentration of pollutants, about 80 percent of which is lactose and 20 percent protein.[60] Several techniques have been developed to reduce the pollution potential of whey and convert lactose and protein residues into industrial products. Water is removed, then extraction of protein is achieved by coagulation in an acid medium, separation by ultrafiltration and several experimental and little used processes. Production of lactose is accomplished through decomposition by microorganisms and other means.

Profitable uses of protein from whey are found in human nutrition, the largest market being cheese manufacturing. Lactose juices can be used for pharmaceutical-type products such as ethyl alcohol, vitamins and antibiotics. Cattle fodder appears to offer a large market for yeast extracts from lactose.

Cyanide-Free Plating System

The Microfinish Co., Inc., of St. Louis, Missouri, U.S.A., provides an example of how a smaller firm — in this case an electroplater — can use commercially available low- or non-pollution technology.[61]

Microfinish has installed a cyanide-free plating system which eliminates the need to treat cyanide pollution. The system is regarded as low-pollution, since treatment is required only for zinc metal in solution, since cyanide is absent. This process also is said to offer advantages in efficiency and energy conservation. Part of the energy savings is from an innovative insulation technique. A layer of 1-inch, polypropylene balls is floated on top of each plating tank to act as an insulator. Heat is kept in the tanks, which reduces electricity requirements by about 25 percent for this portion of the process.

The manufacturer of the cyanide-free system estimates the cost of pollution control at 5 cents per pound of zinc metal in the effluent. The cost of chemicals to treat cyanide in the effluent is estimated at $1.25 to $1.47 per pound, and this sum is saved by having removed the toxic pollutant from the process.

A cost comparison is provided for a hypothetical, typical small plating system — 16 barrels per hour, 250 days per year, or 16,000 barrels per year. It assumes treatment of 12 ounces of cyanide per gallon of plating solution, which would be $8,700 per year. Using a low-cyanide process would reduce the pollution-control cost to $1,624 a year. Using a cyanide-free system, however, reduces the cost to $100 annually.

Other Low- and Non-Pollution Technologies

Ford Motor Company has installed air systems to replace three oil autoclaves used to process laminated windshields by heat and pressure.[62]

The air systems have eliminated the hazard of oil discharge into glass-plant wastewater streams and thereby the need to install and operate a wastewater-treatment facility.

This changeover also reduced operating costs by eliminating a wash process to remove oil traces from completed windshields. Costs were reduced further, because oil no longer was purchased for windshield processing, and steam consumption was reduced to where it equaled an energy savings of 60 percent.

The E.I. du Pont de Nemours & Company converted residue iron chloride into commercial-quality ferric chloride for sale to the wastewater-treatment industry as a sludge conditioner, coagulant and phosphate precipitant.[63]

The company previously had disposed of the material, a byproduct of the chloride titanium dioxide process, by ocean barging from its plant at Edge Moor, Delaware, U.S.A.

A rapidly growing market was forecast for ferric chloride because of federally mandated secondary treatment for most U.S.A. municipal wastewater plants.

Facilities at Edge Moor were installed in 1973 and expanded in 1976 to where they now accommodate the plant's entire iron stream and produce 150,000 tons of ferric chloride annually.

Due to funding relays for municipal wastewater-treatment, the market did not grow as rapidly as initially expected. However, du Pont's sales "have grown rapidly, and the business is showing a positive return on a multi-million-dollar investment."[64] Market growth through the 1980s is expected to consume the entire ferric chloride production of the plant.

One Swedish company, Supra AB, is using conservation methods to create an artificial recreational island while also solving a waste-disposal problem of considerable proportions.

The company, a manufacturer of phosphoric acid, has been ordered to cease the discharge into coastal waters of a gypsum slurry that also contains phosphates and heavy metals.

What Supra did was remove 260,000 tons of sand and rock from an area of shallow water and enclose the area within a stone dike. A polyethylene lining was put in place, and gypsum slurry is being pumped into the area. About 8,000 tons of water is drawn off daily to stabilize the mixture.

The company plans to dump 2.3 million tons of gypsum on the site over a 10-year period. When full, the site will be grassed over and planted with trees, providing the community nearby, Landskrona, with a new, 3.57-hectare recreational island.[65]

Refuse Produces Steam Energy

Refuse Energy Systems Company provides environmentally sound disposal of 2.4 million pounds of refuse daily, which it burns to produce the steam-energy equivalent of 27 million gallons of fuel oil per year.[66]

The company, a joint venture of the Wheelabrator-Frye/DeMatteo Construction companies, also eliminates land disposal of the solid wastes which it burns and produces additional energy conservation through recovery of metal and ash residues.

The facility, located at Saugus, Massachusetts, U.S.A., serves the heavily populated North Shore area of Boston. Steam generated by the plant is purchased by an adjacent energy user, General Electric Co., at a significant discount from its own cost of generation.

In four years from its opening in October 1975, the plant had disposed of more than 500 million pounds of municipal solid waste and produced more than 1 billion pounds of steam. The facility eventually is expected to meet the disposal needs of 500,000 North Shore residents, and is a prototype project for taking advantage of the energy potential from solid waste as part of a comprehensive energy-conservation effort.

The Erie Mining Company of Hoyt Lakes, Minnesota, U.S.A., is converting a barren landfill for mining waste into a wildlife habitat and potential commercial forestland. At the same time, the landfill operation eliminates the need to discharge wastes into nearby lakes and streams.[67]

The company annually mines 30 million tons of taconite, an extremely low-grade, iron-bearing rock. Two thirds of this material, or 20 million tons, comprise a residue called tailings.

These tailings are disposed of in a 2,200-acre landfill which is being revegetated through a careful plan of fertilization according to the natural progression of plant life. This procedure not only creates fertile land from barren wastes, it produces a savings of $74,000 every three years over the alternative landfill approach of chemically stabilizing the mining residues. The benefit to cost ratio is 196 percent.

Nord-Aqua Oy, Vurimiehenpuistikko, Helsinki, Finland, has developed an alternative technology for sea-water desalination which utilizes waste heat and a low-temperature process.[68]

A water stream containing waste heat is partly evaporated in a vacuum, and the vapor is condensed to fresh water in heat exchange with colder cooling water.

This process requires no heating energy consumption compared to conventional distillation processes in which energy is the dominating operating cost. It produces no waste or chemicals and requires no pollution controls to comply with existing standards.

Another Finnish company, Outokumpu Oy, has developed a low-pollution process for Ferro chrome production.[69]

Ordinarily, this involves use of open smelting furnace, from which gases are discharged directly into the atmosphere. This process requires use of high quality chrome ore as the main raw material.

Energy From Waste Gases

Increased demand for environmental protection and a quantum leap in energy prices made it necessary and practical to develop a new furnace that permits cleaning of waste gases and using their energy content elsewhere in the process. Other changes were made to permit use of ore with low chrome content as raw material.

The new process involves wet grinding of ore concentrate which is pelletized and preheated before being fed into an electric smelting furnace. Waste gas from the furnace is cleaned and use in the preheating stage of the process. Dust is recovered from waste-gas purification and brought back to the process through pelletizing.

The Georgia-Pacific Corporation of the U.S.A. is meeting stringent air-pollution requirements in the State of Oregon with a patented new scrubber system to treat exhaust from plywood-veneer dryers.[70]

The system involves colleciton of airborne pitch and reduction to a thick liquid which has the Btu rating equivalent to No. 6 fuel oil. Four units in operation collect enough residue to replace 51,000 gallons of No. 6 fuel oil annually. The company also eventually hopes to use the recovered pitch as a raw material in chemical manufacturing.

The patented scrubber system produces opacity readings of 10 percent or less, well within state requirements. In addition, water used in the separation process of the system is left essentially free of pitch and is recycled.

The Corning Glass Works has developed a cold-crown electric furnace in which raw materials are introduced on the top and melted and refined glass are withdrawn from the bottom. The furnace eliminates the loss of raw material, which vastly reduces air emissions and also allows better process control.[71]

Since 1971, when the first production smelter was started, 14 different glass compositions have been melted in this furance, and air pollution with all of them has been negligible.

Compared to standard furnaces with scrubbers installed, Corning's system annually releases 48,000 pounds less gaseous fluoride and none of the 30,000 pounds of particulate. It also emits 6,000 pounds less fluoride into nearby waterways and creates none of the 4.2 million pounds of sludge left by scrubbers.

Energy savings also are substantial. When melting fluorine opal glass in a furnace with a 100-ton daily capacity, for example, energy consumption is reduced by a factor of 3.5. This factor increases to 3.7, when energy lost to a scrubber is included.

Alternative Technology

In the Soviet Union, the inorganic chemical industry has developed an alternative technology for producing titanium dioxide.[72]

The new process involves steps to thicken sulphuric acid used for decomposition and to thicken acid effluents, which are neutralized with lime milk.

This system resolves ecological problems while reclaiming waste materials to produce products such as industrial gypsum, sulphuric acid and yellow, red and black ferrous pigments.

Fluoride Recycling System

The Aluminum Company of America has developed fluidized-bed technologies to refine and smelt aluminum more efficiently while reducing pollution and conserving energy. Four projects are involved.[73]

The first project was development of Process 389, a dry-scrubbing system for fluoride emission control from aluminum smelting pots. With total conversion to this system, Alcoa anticipates a savings of 80 million gallons of water daily. The process also can capture and recycle more than 99 percent of total fluoride content of collecting fumes from hooded smelting cells. The process reduces fluoride requirements by more than 50 percent.

The second process has enabled Alcoa to control carbon-baking furnace emissions, historically a difficult problem. This process eliminates the need for large quantities of water and extensive water-treatment facilities.

The third project involves development of an alumina flash calciner, which produces an energy savings of 30 percent per pound of alumina through better heat exchange and reduced radiant losses. It also has proven to be less expensive to build and maintain than other treatment systems.

The fourth project involves a fundamental change in smelting technology which cost $25 million to develop over 15 years. It produces aluminum chloride, which is reduced to aluminum and chloride. The aluminum is withdrawn, and the chlorine is recycled in a closed system. Fluoride emissions are eliminated with this method, which has a cell-energy efficiency of 80 percent, compared with 45 percent for conventional (Hall Process) smelting systems.

Chapter Seven

Conclusions and Recommendations

Information is the prelude to understanding, and understanding is the overture to cooperation. This fact sets the stage for the general conclusion of this overview of low- or non-pollution technology. It is this: Cooperation is essential between government and industry, if environmental legislation and regulation are to be effective, enforcement is to be equitable, and these new preventive approaches are to work.

Achieving such cooperation requires mutual understanding of three environmental realities: the issues are emotional; the decisions are political, but the solutions basically are technical.

No technical solution can be accepted if it is not presented in harmony with the emotional and political realities. Conversely, no law, regulation or wish can force a technical solution where none exists, and there is neither reasonable time nor resources for its development and implementation.[74]

Low- and non-pollution technology through pollution prevention appears to offer the best long-range approach to resolving these problems and achieving effective pollution control as well as resource recovery and resource conservation. It is recommended that this alternative environmental approach be used wherever and whenever possible.

There are industrial processes, however, which cannot be changed easily, if at all. Changeover may be too costly, or there may be no pollution-prevention technology which is applicable. Many heavy industries are examples of such complexity. This should be recognized and understood. The concept should not — cannot — be forced where it is inapplicable or unworkable.

Low- or non-pollution concepts offer special opportunities for developing nations which are establishing or expanding their industrial base. They can introduce the technology simultaneously with new production, thereby avoiding many of the environmental problems which developed lands had had to solve, at great expense, by adding pollution controls to established production systems. For instance, the United States and Federal Republic of Germany have had to expend copious amounts of money, manpower and natural resources to control pollution which was created in the production cycle.

There are many long-term benefits from low- and non-pollution technology, including the diversion of scarce capital and other resources from non-productive pollution control into productive economic growth or for myriad other needs of society seeking to raise its living standards.

Industry, Government Cooperation

Regardless of whether a nation is developing or developed, however, it must have excellent cooperation between the industrial and governmental sectors to establish a productive program of low- or non-pollution technology. Coordinated programs are required on all levels to encourage these concepts.

In industry, this includes establishing a program to inform its employees, especially the engineers, scientists and technicians about the concepts and benefits of low- or non-pollution technology and encourage their efforts along these lines. Interest should be sustained by personal and professional recognition efforts supplemented by a long-term, intensive informational program. An example which contains all of these elements is 3M's "Pollution Prevention Pays" (3P) Program.[75]

In government, this involves conducting informational programs and research and development to provide the seeds from which a crop of innovative ideas can be harvested, as described in Chapter 4. It's particularly important to provide this support for industries which potentially can use the concept, but are unable to do so for themselves, by reason of small size or lack of technical sophistication.

Government also should be responsible for seeing that laws and regulations not only eliminate obstacles to low- and non-waste technology but actually encourage its development. Providing financial incentives in a manner suitable to the country's economic system is a major area of government responsibility.[76]

Working together, industry and government should exchange information to spread the conserver concept more widely and establish a base of public awareness and support for the program. Achieving public confidence and understanding is particularly important, so converted residues will be accepted as resources, and low- or non-pollution products will achieve marketplace advantage. These are goals which are desirable and attainable for both developing and developed nations.

---

[1] *"Non-Waste Technology and Production," proceedings of a seminar held by the United Nations Economic Commission for Europe, Nov. 29-Dec. 4, 1976, Paris, France, p. xiii.*

[2] *Saleh, Hussein, Advanced Concepts Centre, Environment Canada, Ottawa, Canada. "A Broader Definition of Non-Waste Technology," ECE Seminar reports, p. 25.*

[3] *International Labour Organization (ILO), Management Development Branch. "Environmental Aspects of Modern Management," 1978, pp. 1-2.*

[4] *"Non-Waste Technology and Production," op. cit., p. xiv.*

[5] *Ling, Joseph T., vice president of environmental engineering and pollution control, 3M Company, St. Paul, Minnesota, U.S.A. "Resource Conservation Pollution Control Technology: An Idea Whose Time Has Come," speech delivered at the 1977 (U.S.A.) National Conference on Treatment and Disposal of Industrial Wastewaters and Residues, Houston, Texas, April 27, 1977.*

[6] *Lehr, Lewis W., chairman and chief executive officer, 3M Company. "Pollution Prevention Pays," principal industrial address delivered at an industry-government seminar on pollution-prevention technology, Chicago, Illinois, Jan. 17, 1977, p. 3.*

[7] *Ling, Joseph T., "Non-Waste Technology, the 3M Case," paper prepared for delivery at the International Environmental Management Seminar, Centre d'Etudes Industrielles, Geneva, Switzerland, Jan. 31, 1977.*

[8] *Susag, Russell H., director of environmental regulatory operations, 3M Company. "Productivity in Environmental Management: Eliminating Pollution at the Source." Remarks delivered at the 25th annual Joint Engineering Management Conference, Cincinnati, Ohio, Oct. 31, 1977, as reported in the conference proceedings.*

[9] *Lehr, Lewis W., "Preventing Pollution Pays," Financier Magazine, Vol. V, No. 12, December 1981, p. 17. The author cites figures from the Council for Environmental Quality's 1980 annual report and the U.S. 1980 census.*

[10] *University of California, Los Angeles, Base Forecast, National Business Forecast, 1978, Table 3.*

[11] *Gelb, Bernard A., and Meyers, John G., The Conference Board, Division of Public Affairs Research. "Measuring the Cost of Industrial Water Pollution Control," Table 14, p. 61.*

[12] *Ibid.*

[13] *Ibid.*

[14] *Minutes of the Preparatory Meeting for the ECE Seminar, "Non-Waste Technology and Production," op. cit., para 39.*

[15] *Ling, Joseph T., Remarks to Students and Faculty, Austin College, Sherman, Texas, March 11, 1975.*

[16] *CMEA Countries Symposium, March 16-19, 1976. "Theoretical, Technical and Economic Aspects of Low-Waste and Non-Waste Technology," ECE Seminar reports, p. 15. Held in Dresden, German Democratic Republic, the symposium was attended by representatives of the G.D.R., People's Republic of Bulgaria, Hungarian People's Republic, Polish People's Republic, the U.S.S.R. and Czechoslovak Socialist Republic.*

[17] *Neddens, Martin, Rat von Sachverstandigen für Umweltfragen, Wiesbaden, Federal Republic of Germany. "Administrative Ways and Means of Implementing Non-Waste Technology," ECE Seminar reports, p. 621.*

[18] *Ling, Joseph T., "3M Resource Conservation Program Attacks Pollution at Its Sources," Pollution Engineering Magazine, Vol. 9, No. 5, May 1977, p. 30.*

[19] *Vegh, Jeno, economist/consultant. "For a Sound Economy," Enterprise Magazine, publication of the U.S. National Association of Manufacturers, Vol. 1, No. 6, July 1977, p. 8.*

[20] *Malaska, Pentti, Turku School of Economics, Turku, Finland. "Concepts and Principles of Non-Waste Technology," ECE Seminar reports, pp. 33-34.*

[21] *Bhatia, Salim, and Jump, Robert. "Metal Recovery Makes Good Sense," Environmental Science & Technology Magazine, Vol. 11, No. 8, August 1977, pp. 752-755.*

[22] *International Labour Organization, op. cit., p. 11.*

[23] *United Nations Environment Programme and Food and Agricultural Organization of the United Nations. "Residue Utilization Management of Agricultural and Agro-Industrial Residues," an Overview, May 1977. Chapter 4, Recommendations, p. 21.*

[24] *Royston, Michael G., environmental faculty, Centre d'Etudes Industrielles, Geneva, Switzerland. "Eco-Productivity: A Positive Approach to Non-Waste Technology," ECE Seminar reports, p. 39.*

[25] *Ibid.*

[26] *Fischer, M., vice rector, Institute for Systems Engineering and Innovation Research, Federal Republic of Germany. "Non-Waste Technology and the Materials Flow in an Economy: Facts and Perspectives," ECE Seminar reports, p. 661.*

[27] *Van den Kroonenberg, H.H., Twente University of Technology, Enschede, The Netherlands. "The Role of Design Education in Non-Waste Technology," ECE Seminar reports, p. 585.*

[28] *Lehr, Lewis W., "Pollution Prevention Pays," op. cit.*

[29] *"Non-Waste Technology and Production," op. cit.*

[30] *The conferences were: "Beyond Environmental Regulation: Industry Takes the Initiative," Chicago, Illinois; "Industrial Initiatives in Pollution Control," Boston, Massachusetts; "Profits Through Accomplishments in Pollution Control," Dallas, Texas, and "Pollution Imagineering Costs Less," San Francisco, California. They were intended to provide forums for industry-government information exchanges.*

[31] *The CMEA countries, however, met six months prior to the ECE Seminar to discuss pollution prevention. Their program was held March 16-19, 1976, and was entitled, "Theoretical, Technical and Economic Aspects of Low-Waste and Non-Waste Technology." Additional details are in footnote 16.*

[32] *"Government-Industry Accord Seen on Ecology, Related Issues," ChemEcology Magazine, publication of the U.S. Manufacturing Chemists Association, January 1978.*

[33] Halsam, C.L., general counsel, U.S. Department of Commerce. Remarks at the environmental conference "Profits Through Accomplishments in Pollution Control." Dallas, Texas, Sept. 8-9, 1977.

[34] Ling, Joseph T., remarks at panel discussion, Advisory Committee on Federal Policy on Industrial Innovation: Environmental Safety and Health Subcommittee, Oct. 19,1978.

[35] Facht, J., "Guidelines for the Compilation of a Compendium on Low- and Non-Waste Technology," Secretariat, United Nations Economic Commission for Europe, GE.78-52305. This document was the basis for discussion of L/NWT at the May 1979 ministerial meeting of the ECE.

[36] Huissoud, R. Conseil National du Patronat Francais, Paris, France. "Statutory and Financial Provisions for the Establishment of Manufacturing Methods Free of Waste Products." ECE Seminar reports, pp. 605-607.

[37] Lehr, Lewis W., "Pollution Prevention Pays: 3M Company Encourages Technology That Will Prevent Pollution, Not Just Control It." Catalyst for Environmental Quality Magazine, Vol. VI, No. 3, 1978, pp. 14-18.

[38] Ibid.

[39] Pollution Prevention Pays Program Status Report, 3M Company, March 1982.

[40] Ibid.

[41] Ling, Joseph T., various speeches and papers.

[42] Tolba, Mostafa K., executive director, United Nations Environment Programme. "Cost Benefit Evaluation of Environmental Protection Measures," Report No. 78-4285.

[43] Susag, Russell H., New York Journal of Commerce, 1978 special issue for the American Chemical Society annual meeting.,

[44] Bohon, Robert L., manager, environmental laboratory, 3M Company. "Management of Monitoring Systems." Paper delivered at an industry-government seminar on pollution-prevention technology, Chicago, Illinois, Jan. 17, 1977, p. 3.

[45] Cicchetti, Charles J., University of Wisconsin, Madison, Wisconsin. "Introductory Report, Cost/Benefit Aspects of Non-Waste Technology." ECE Seminar reports, pp. 529-533.

[46] Gelb, Bernard A., and Myers, John G., U.S. Conference Board, op. cit.

[47] Ibid. The study included these industries: (1) Pulp, Paper and Paperboard Mills; (2) Alkalines and Chlorine; (3) Industrial Organic Chemicals; (4) Petroleum Refining, and (5) Blast Furnaces and Steel Mills.

[48] Picard, J., director, Agence Financiere de Bassin, Loire-Bretagne, France. "Cost-Benefit Considerations in Waste-Free Production Methods." ECE Seminar reports, pp. 533-546.

[49] Facht, J., U.N. Economic Commission for Europe, op. cit.

[50] Gustkowicz, Stefan, Committee of Science and Technology, Warsaw, Poland. "Some Aspects of Production Without Waste of Mineral Raw Materials in Poland." ECE Seminar reports, pp. 105-119.

[51] Information supplied by 3M.

[52] "Going the Water Reuse Route," Environmental Science and Technology Magazine, Vol. 12, No. 8, Aug. 1978, pp. 877-878.

[53] Rauch, Robert. Memo to Environmental Defense Fund quoting Mr. C.A. Gerstacker, chairman of the board, Dow Chemical Corp.

[54] "Going the Water Reuse Route," op. cit., p. 877.

[55] "Wanted: Better Ways to Clean Water," Environmental Science and Technology Magazine, Vol. 11, No. 8, August 1977, pp. 748-749.

[56] Ibid.

[57] Htun, Nay, senior programme officer, United Nations Environment Programme, Paris, France. Compendium of low- and non-pollution technology examples, December 1978.

[58] Kluge, W., Institute of Energetics, Leipzig, German Democratic Republic. "The design of Non-Waste Technologies Taking the Example of a Lignite Transformation Complex in the German Democratic Republic." ECE SEminar reports, pp. 351-354.

[59] Greene, J.R., General Motors Corp., Warren, Mich. "Chromium Recovery at Guide Division, General Motors Corp." Paper supplied by Mr. W.R. Johnson, director of plant engineering, Environmental Activities Staff, General Motors.

[60] Bertrand, F., engineer, Centre Technique du Genie Rural des Eaux et des Forets, Ministere de l'Agriculture, Antony, France. "Profitable Industrial Uses of Whey." ECE Seminar reports, pp. 213-219.

[61] Smith, Stanley W., president, and Kemper, Thomas J., vice president, Microfinish Co., Inc., St. Louis, Missouri, U.S.A. Case-study of their company's cyanide-free plating system. Information about the product, Kenlevel II non-ammoniated chloride zinc, supplied by the manufacturer, 3M Company. The project which developed this product received a Pollution Prevention Pays (3P) Award from the company. The 3P Program is described elsewhere in this document.

[62] Sussman, V.H., director, Stationary Source Environmental Control, Environmental and Safety Engineering, Ford Motor Company, Dearborn, Mich. Case study supplied for this publication.

[63] Parsons, J.T., consultant manager, Environmental Engineering, E.I. du Pont de Nemours & Company, Wilmington, Del., Correspondence.

[64] Ibid.

[65] Elkington, John. "The Ecology of Tomorrow's World — Industry's Environment," published by Associated Business Press, London, England, 1980, p. 146.

[66] Htun, Nay, United Nations Environment Programme, op. cit.

[67] Htun, Nay, United Nations Environment Programme, op. cit.

[68] Economic Commission for Europe (ECE). "Compendium on Low- and Non-Waste Technology." Summary from Nord-Aqua Oy, Vuorimiehenpuistikko, Helsinki, Finland, March 29, 1979.

[69] ECE, Ibid. Summary from Outokumpu Oy, Espoo, Finland, May 20, 1979.

[70] Htun, Nay, United Nations Environment Programme, op. cit.

[71] Htun, Nay, United Nations Environment Programme, op. cit.

[72] ECE, op. cit., Summary from the Federal Ministry for Technical Development and Investments, U.S.S.R., December 15, 1979.

[73] Htun, Nay, United Nations Environment Programme, op. cit.

[74] Ling, Joseph T., "Resource-Conservation Technology: An Idea Whose Time Has Come." Fourth annual National Association of Manufacturers Industry/Government Dialogue for Action, Washington, D.C., March 25, 1977.

[75] The "Pollution Prevention Pays" Program is described in Chapter 4.

[76] Recommended governmental actions and encouragements are suggested in detail in Chapter 4.